SCIENTIFIC AMERICAN SUPPLEMENT. No. 1558

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Scientific American, established 1845.
Scientific American Supplement, Vol. LX, No. 1558 } NEW YORK, NOVEMBER 11, 1905. { Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.

AN ENGLISH ELECTRIC SYSTEM OF RAILWAY SIGNALING.*

By F. C. PERKINS.

The Webb & Thompson electric point and signal apparatus was chosen for the London and North-Western Railway Company after exhaustive trials had been made, and the accompanying photographs and drawings illustrate the devices used on one of the numerous signal cabins at Crewe, which will contain more than one thousand levers.

It is claimed by many prominent engineers that the working of points and signals by power is very desirable in stations involving the movement of a very large number of levers. This not only relieves the signalman of the severe work caused by the manual system, but also enables him to watch more closely the train movements, and the position of signals and points.

The electric power working of railway points and signals also avoids the necessity of having a large number of men in the signal cabin, and the responsibility is therefore not divided among so large a number. Several systems have been developed in this country, as well as in England, Germany, and Italy, and in each case they possess features which are said to be more or less specially suited to different requirements of the several countries in which they have been produced. In England, when the first power station was proposed, the interlocking of points and signals had practically been completed, the work had been carried out at an enormous cost, and although the advantages of power working were fully recognized, there was naturally some reluctance to incur the further outlay which a reconstruction of existing apparatus would have involved; consequently, progress in England has been slow, and it is only now, when reconstruction is becoming necessary, and the enlargement of stations involves a rearrangement of the signal plant, that power working is being adopted.

In America, however, the power system was available before any great progress had been made in the interlocking of points and signals. Through the courtesy of Mr. F. B. Webb, chief mechanical engineer of the London and North-Western Railroad, I am enabled to give the following description and accompanying diagrams and photographs of this English system.

The English "Crewe system" is an electric system, this form of power being chosen as being more suitable for the actuation of points and signals than any other. It was installed by the Railway Signal Company, Ltd., of Fazakerley, Liverpool. It is the power that is used for lighting, and being already very generally provided for this purpose, no additional plant would be required in the generality of cases for a point and signal installation. Moreover, the same electric current which works the signal also lights it, the signalman lighting up all his signals at the proper moment by means of switches in his cabin, thus dispensing with the troublesome duty entailed with the present system.

It is a power that is largely used for the working of capstans, cranes, lifts, and other machinery required for railway purposes, and it is not necessary to point out the great advantage of having one generating plant for all these various requirements.

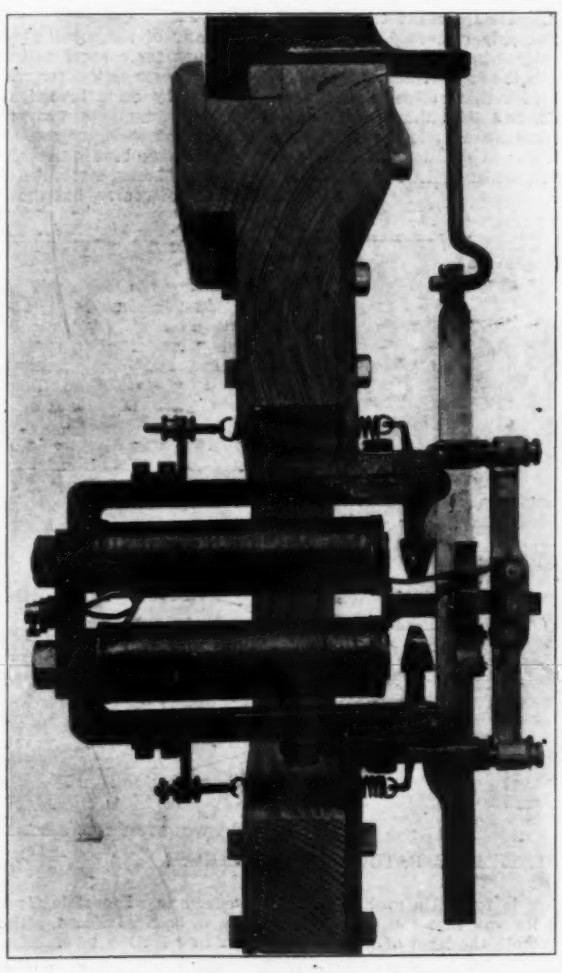
Further, it is a power which can be obtained in most towns from a local supply company, thus avoiding the necessity for a railway company to provide an independent plant; and finally, electricity is the readiest power applied to a track circuit system of automatic signaling—a system which is likely in the near future to be introduced more largely for the working of intermediate block posts.

The system is in operation at the Crewe station of the London and North-Western Railway Company The first signal cabin, containing 60 levers, was completed and put to work nearly four years ago, and since then four more cabins have been put to work, containing 152, 95, 75, and 57 levers respectively. Five more cabins will complete the work, one of which will contain the unprecedented number of 350 levers, and the whole will then constitute the largest power installation in the world. It is understood that further large works are in contemplation, and there is no doubt that the choice of a power system by this, the premier railway company of England, is finally made.

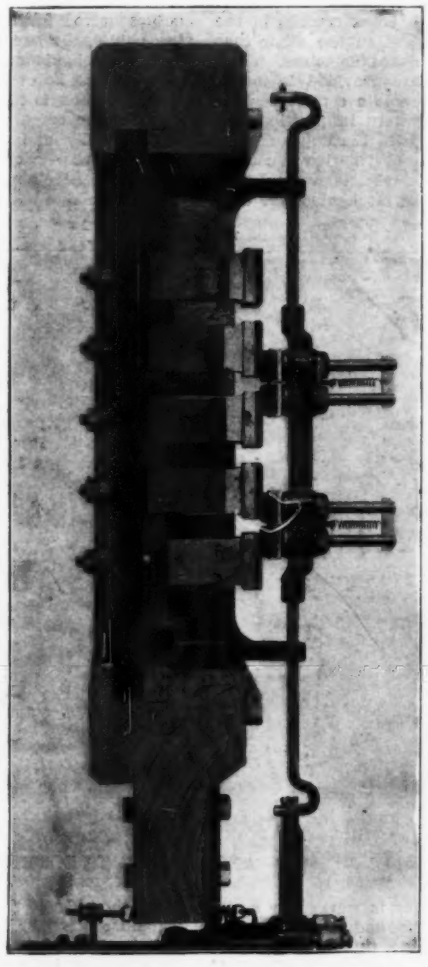
The Gresty Lane signal cabin at Crewe was put to work about four years ago, and controls a busy junction on the Crewe and Shrewsbury main lines. The levers, 60 in number, it will be noticed, are in two tiers, the upper tier being as a rule used for point movements, and the lower tier for signal movements, and it will be seen how compact this comparatively large frame is, occupying a space about one-third of that required for an ordinary apparatus, the signalman from one position in the box being able to operate some 30 levers. In another signal cabin containing 152 levers, a frame of 76 levers is fixed on one side of the box, and 76 on the other, the signalman working between them, and in this case he is able without moving his position to work nearly 60 of the levers.

Nothing but the levers and supporting frame are in the top part of the signal cabin, and the work of the signalman is consequently not interfered with by any adjustment or re-

THE INTERIOR OF THE GRESTY LANE SIGNAL TOWER.



CHECK LOCK FOR DETECTING MOVEMENT OF POINTS.



SWITCH FOR DIRECTING THE CURRENT TO POINT OF SIGNAL.

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*Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

pair of the locking switches or controlling apparatus. It will be noticed that the signalman in the photograph is moving a lever in the frame and at the same time working his block instruments, which illustrates the ease with which the Crewe system is worked.

The bottom floor of the signal cabin contains the interlocking, the electric switches, and the check locks. The interlocking is mechanical, and being of the well-

FACING POINT SWITCH WITH MOTOR AND CHECK LOCK.

known tappet type, does not need any further description. Below the interlocking are the switches, by means of which the electric current is transmitted from the supply source to the points or the signals, and below the switches again are the check locks. These are provided for the point levers only, and prevent the complete movement of the levers until the points they operate have been moved over to the right position and securely bolted.

The facing point and cast-iron boxes contain in the one case the point movement, and in the other case the check lock switches and signal detecters, which in addition to the check lock are provided to insure that a signal reading over the points cannot be lowered until the points are accurately in position and bolted. These covers are level with the upper face of the sleepers and ballast; thus no obstruction is caused, and a level footway is formed for shunters.

An electric motor and a special mechanism are used for working a point. The motor is worked by a current of 20 amperes and 100 volts, and runs at a speed of about 800 revolutions a minute, this speed enabling the points to be moved over in about three seconds.

The armature is formed on a tube which fits over the armature shaft, and it can be lifted off and a new armature substituted in a few moments. The armature shaft is provided with ball bearings, and drives a worm and worm wheel. The worm wheel is loose on a cross shaft, and its movement is transmitted to the cross shaft by means of two clutches, one on either side; these clutches are made right and left handed, so that if the worm wheel is turned in one direction one clutch will be engaged and will turn the cross shaft, say to the right; in the opposite direction the other clutch will be engaged turning the cross shaft to the left. When the point has been moved over and bolted, a striking gear is operated which disengages the clutch, and the motor then runs free. Keyed to the cross shaft is a cam wheel, on either face of which is formed a cam-shaped slot of an irregular contour; in each slot there works a roller attached to a bell crank, the one crank working the point and the other the locking bar and bolt. This locking bar and bolt is only required for facing points; in the case of trailing points, the one crank only is needed. The motor and its mechanism are placed in a cast-iron box with a cover, which is level with the top surface of the sleepers. The box is filled with thick mineral oil to the level of the cross shaft, and thus the mechanism is automatically and continually supplied with lubrication; one charge of oil has in practice been found to last for eighteen months, when a little fresh oil has to be added.

In the side of the box is formed a syphon, so that should any water find its way into the box it would fall to the bottom of the oil, the level of which would be raised, and the water at once syphoned away. Very little water in practice is found to get into the box, but in the event of a box being filled by accident, the syphon being inoperative, no harm results if the water is all cleared off in the course of twenty-four hours.

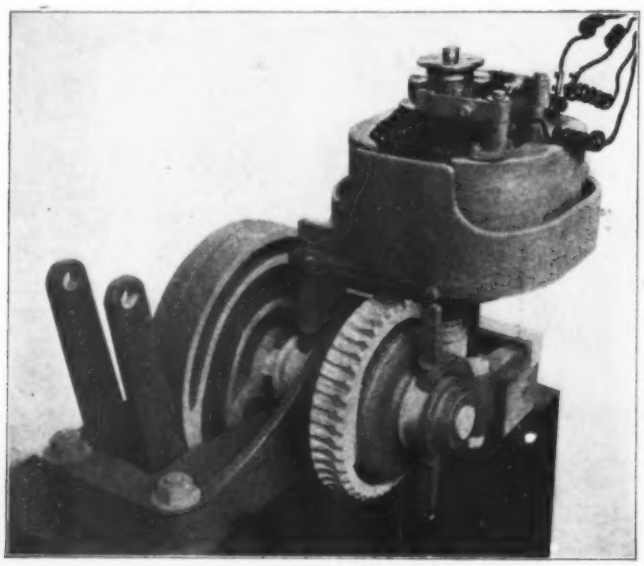
Points are worked by means of a cable about three-quarters of an inch in diameter, and this can be laid in the ground or carried on supports overhead; when laid in the ground it is put in rough grooved timber, and pitched in.

In the switch by means of which the current is directed from its source of supply to a point or a signal, the contacts are of carbon, the carbons on the moving part being carried on plungers which are duplicated to insure a good contact if the surface of the under carbons is irregular. The connection between the supply cables and the switch is made by metal jaws, and in case of any failure the complete switch can be taken out and another substituted in a few seconds. Experience, however, has proved that the failure of one of these switches is of very rare occurrence, switches which have been in constant work for eighteen months so far showing no signs of deterioration.

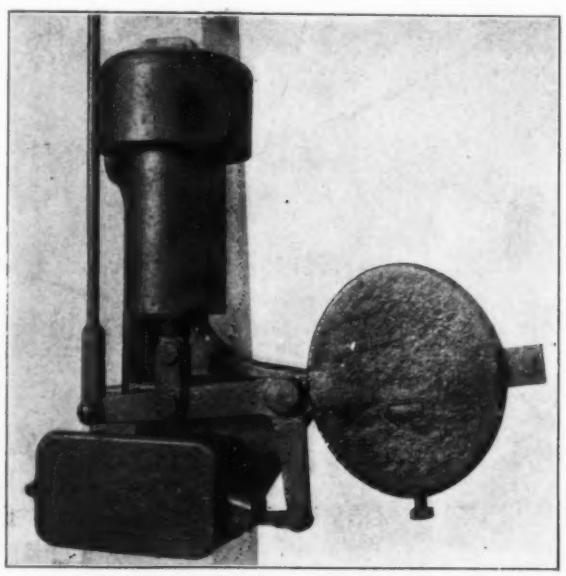
The check lock is provided for point levers only. In a power system it is quite necessary that a signalman must not be able to complete the movement of a lever which would complete the unlocking of signals in connection with the point until the point has been moved over and bolted, and the check lock is provided for this purpose. It consists of two electro-magnets, one being energized when the point is pulled over, and the other when the point is put back. The energizing of the coils is caused by a shunt current switched on when the bolt lock to secure the point in position is shot. The rod working across the face of the magnets is provided, it will be seen, with two projections, one of which is shown to be engaged with the pawl which forms the armature of the left-hand magnet. In this position the lever in the cabin is pulled over through about three-quarters of its stroke, and so soon as the points have been moved over and locked the left-hand magnet will be energized, the armature pawl will be drawn down and the rod released, thus enabling the lever in the cabin to be fully pulled over.

The signal movement consists of an electro-magnet combined with a solenoid, a switch with carbon contacts, and a small resistance frame. This movement is somewhat similar in construction to the movement introduced by Mr. Ilius A. Timmis, and provided by him for the automatic electric signals of the Liverpool overhead railway, which have been working most successfully for many years. The movement has been simplified and improved, and is of greater power, as it has to work a much larger and heavier signal arm. A current of about 15 amperes and 100 volts is required for a fraction of a second to pull the signal arm to the "off" position, when the switch passes this current through a resistance, reducing it to about 2 amperes, which is sufficient to hold the signal arm off. When the current is cut off by the lever in the cabin being put back, the arm at once flies to danger.

A somewhat similar but smaller movement is employed for ground disk signals.



ELECTRIC POINT MOTOR.



MOTOR FOR WORKING THE SIGNALS.

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THEORY OF COHERER ACTION.

MANY of the theories which have been advanced to account for coherer action are undoubtedly plausible, and coherer action (or rather the particular action observed by some investigator) might be explained by that investigator's theory; but what is wanted is a theory which shall embrace the multiplicity of phenomena which have been observed, as well as to explain away that stumbling-block, self-decohesion. There can be no doubt, of course, but the bewildering array of coherer effects is responsible for the numerous theories which have been advanced, although the inevitable tendency is now setting in of disregarding those which explain only one particular effect, and the number may be reduced to three of the best known. These are Lodge's welding theory, Branly's hypothesis of the modification of the dielectric, and Bose's theory, which assumes that

allotropic modifications of the metals are caused by the electric influence. One other may, however, be mentioned, the latest—that due to Dr. Guthe, and was given in a paper read before the St. Louis Congress. In it an attempt is made to form a theory which embraces all the phenomena which have been observed, although it also is unable to account for the decoherence produced by heat. Comparing for the moment Branly's and Lodge's theories, we find that not only do they explain particular effects merely, but they also militate against each other in some respects. The experiment, for instance, with the solid dielectric seems scarcely compatible with a theory of the welding of the embedded particles, while, as already mentioned, the measurement of the resistance by means of alternating currents supports the welding theory, as well as disposes of the assumption of the modification of the dielectric. A theory of welding also does not seem to agree with the effects produced on carbon particles by electric waves, because it is scarcely possible to talk of the fusion of carbon granules, and at the same time it is not quite clear how the electric oscillations produce partial volatilization of copper particles. Dr. Lee de Forest, in a paper read before the St. Louis Congress, thinks that the explanations offered by Lodge and Branly may both be correct under different conditions. The Branly effect seems to be borne out by the fact that among the particles of the carbon coherer with their roughened surfaces there almost necessarily exist gas molecules which cling to the particles; and if this is assumed to be the case we may suppose the gaseous dielectric film to be punctured by a spark; but after the spark has passed the film immediately interposes itself again, so that the self-decohering properties of the carbon detector seem to be triumphantly explained. Then some one pointed out that an increase of temperature is favorable to the return of the high resistance. Now heat is known to be capable of ionizing air molecules, and it has long been the custom to consider that ionization of the air or surrounding gas took place before a spark passed. We used to say, when asked why a charged body, be it ever so well insulated, lost its charge, that it was due to defective insulation, dampness, and so forth; but the familiar experiment with a Bunsen burner and a charged metal cylinder, by showing ionization of the air to have taken place, affords the real clue. Here, then, is the condition which might be expected to be favorable to coherence—namely, the heating of the tube—but, instead, the heat obstinately refuses to help coherence, and actually produces the reverse action. Again, Branly's hypothesis in regard to the modification of the dielectric by means of the electric oscillations, rendering it to some extent conducting, leaves it to be inferred that distance between the particles has no effect. For, according to such a hypothesis, all that is necessary to produce coherence is to make the oscillations of sufficient magnitude, and thereby eliminate the effect of distance. This, however, is negatived by Branly's own experiments and by those of other investigators, who have shown that, unless the dielectric is extremely thin, the coherer action is altogether suppressed. It has also been shown that the nature of the dielectric has little or no effect, unless it be considerably viscous or unless electrolytic actions are called into play.

Bose's theory is that the metals are capable of assuming an allotropic modification when subjected to the electric stimulus; but more particularly is this assumed to be the case with the carbon coherer, and Bose was led to the conclusion that allotropic modifications were sufficient to account for the self-decohering characters of the carbon coherer. It is supposed that one of the forms has a high, while the other has a low, specific resistance, and that excessive molecular strains are set up due to the new molecular arrangement, producing a return to the old form, and also conveniently explaining away self-decoherence. Here again it seems that the true solution to the riddle has been found, until it was found that the decoherence would also occur even when the variation of the E.M.F., which produced the coherence, had been exceedingly slow. This indicated that no great strains were likely to have been produced, and as a death-blow to the allotropic modification theory, similar effects were observed when a steady difference of potential was used.

From any point of view Bose's theory only introduces complications, and besides it is not so comprehensive as Lodge's. Recent research, however, has brought to light some new phenomena, one of which is that a certain critical voltage is necessary, or, in other words, a certain minimum difference of potential is required across the terminals of the coherer before the slightest increase in the conductivity can take place. Aschkinass defined the critical voltage as that voltage which, when applied to the coherer, just makes it impossible to decohere again without tapping. Dr. Guthe, in his paper on "Coherer Action," read before the St. Louis Congress, found, in conjunction with Trowbridge, that for a given E. M. F. in the circuit the potential difference between the terminals of the coherer, when plotted as functions of the current, shows for weak currents only a slight diminution of resistance, but for comparatively strong currents the curve suddenly bends and becomes horizontal, the value of the ordinate when the curve approaches this asymptotic line being defined as the critical voltage. Guthe found for the single contact coherer, which he used in preference to the filings coherer, in order to obtain as nearly as possible the same conditions every time, that the critical voltage lay between 0.05 and 0.25 volt.

With this short preliminary of the experiments, which are the basis of Guthe's theory, we shall now proceed to treat of it, and thereby bring the subject down to the latest researches. At the outset, Guthe assumes that an electrostatic attraction is one of the principal factors in cohesion. We have already seen how Lodge illustrated the effect of electrostatic attraction; but Guthe, in collaboration with Trowbridge, illustrates this effect in a different way, by means of a single-contact steel coherer in series with a galvanometer and a battery with a regulator for supplying current at different E. M. F.'s in different experiments. With these different E.M.F.'s, of course the P.D.'s at the coherer terminals were also different, and when the latter were plotted as functions of the current, the graphs obtained were all distinct from each other. But when the terminal P.D.'s and the reciprocals of the resistances were plotted with the latter as abscissæ—that is to say, when the P.D.'s were made functions of the conductivity—a single curve was obtained for the series. The results, as shown by the curves, were that the resistance of the coherer is inversely proportional to the applied E.M.F., and so long as the latter is a constant, the conductivity of the coherer remains unchanged until the difference of potential rises to the critical voltage. On the other hand, if the E.M.F. be increased, the external resistance remaining constant, a decrease in the resistance of the coherer is observed, and on breaking the circuit a partial return to the original condition takes place. To dispel any doubt as to the smallness of the distances separating the particles when cohesion is produced, Guthe has shown, from his results of the critical voltage of various metals, that, for silver with a critical voltage of 0.062, and for iron 0.22 volt, this only allows a distance between the particles when coherence sets in of 3.5×10^{-5} centimeters and 13.3×10^{-5} centimeters respectively, or the distances are of the order of one one-hundredth-millionth of an inch. Guthe's theory, then, is that coherer action is produced by the passage of electrons from the negatively charged particles to those positively charged, thereby accounting for the metallic resistance found by an alternating current measurement. The reason why permanent cohesion is not observed will be understood by reference to theories of electrons. J. J. Thomson shows ("Conduction of Electricity through Gases") that the attraction between the electrons and the metal is given by $\frac{e^2}{4r^2}$ where e is the charge on one electron, and r the distance of the electron from the surface of the metal. In the case of the coherer, as shown by Guthe, there is over and above the free electrons which modern theory asserts to be moving about in the metal in every direction, an electrostatic attraction, which by increasing the kinetic energy of the electrons, assists it to leave the metal. When the molecular range of the metals has been sufficiently increased, an increase in the energy supplied at the terminals will only produce a greater current, while the potential difference will remain constant. This carriage of electricity cannot be termed a spark, even disregarding the short distance, since the heating effect of the spark is absent. A pressure at right angles to the direction of the current accompanies its passage, squeezing out the molecules of the dielectric and producing a continuous metallic circuit. The resistance is now permanently lowered, and except in some cases, requires a mechanical shock to produce decoherence. What, then, is the true action of the tapping? It has been observed that if the electrodes be separated, the dielectric again interposes itself between the particles, and the previous high resistance is reproduced. If, immediately after separation, the particles be brought together again at the same point, as could be done for instance by reversing, the dielectric has not found time to condense on the particles, and the resistance is still low. We see, then, that tapping displaces the particles from their positions relatively to each other, producing new points of contact where the dielectric has not yet been removed. Dr. Guthe also observed that heat applied to a single-contact coherer produced a considerable increase of conductivity, while the critical voltage fell almost to zero; this, of course, is an effect that should be expected, and seems to bear out the theory. These conclusions were only held by Dr. Guthe to be valid for coherers in which the metallic areas in contact were sufficiently large to produce all the electrons necessary to carry the current; but if the particles form contact at sharp points, such as are found in the carbon coherer, another effect is introduced. It is held that an ionization of the surrounding gas must take place, and that it assists the transference of the electrons, but disappears again when the excitation ceases. As the ionization depends on energy supplied, the resistance must become smaller when the E.M.F. is increased, and will have a high value when the E.M.F. is low. With a constant E.M.F. in the circuit and an external resistance, coherence takes place when the P.D. reaches a certain critical value; but at this point the resistance is low; hence the P.D. becomes less, and it may be that a recombination of the gas molecules takes place. This, in turn, produces a greater P.D. by increasing the resistance. The resistances and the E.M.F.'s in the circuit to produce these alterations are such that coherer action is just on the verge of being produced, and the effect may be in turn the cause of the musical sounds heard by some investigators. Guthe's conclusions point to two distinct cases—one in which conduction is produced by means of electrons, and the other in which ions of the surrounding gas are the carriers of the electricity; but it is thought that there is probably a mixture of the two actions in most coherers. "The partial return to the higher resistance on lowering the applied E.M.F. noticed by Bose and others points to this conclusion."

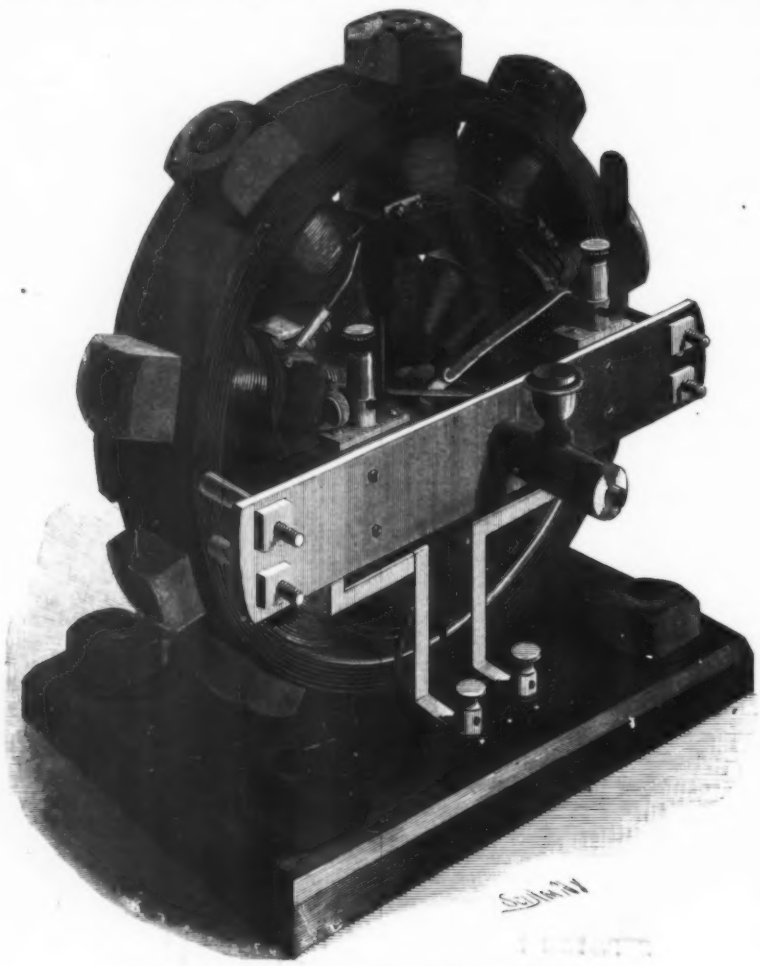
The coherers which we have been considering have all a different action from the electrolytic coherer, and one of their main drawbacks is the necessity for tapping back. Dr. Lee de Forest has developed the theory of the electrolytic receiver, as he calls it, very thoroughly, and the action does not seem to be so obscure as the action of the metallic coherer. The first mention of an electrolytic coherer was in 1898, when a German experimenter, taking a small mirror and drawing a sharp razor over the silver surface at the back, produced a narrow gap between two silvered edges; the opposite sides of the gap were then connected to a battery, a galvanometer, and a telephone receiver all in series. Nothing was observed until a film of moisture was produced on the gap by placing a drop of water across it, and then the galvanometer needle was first violently deflected, followed afterward by its taking up a stationary position; this indicated that the resistance of the gap had broken down, being now only of the order of a few ohms. If, now, a Hertz oscillator were set into operation in the neighborhood, the galvanometer deflection decreased, indicating an increase of the resistance; but on the cessation of the electric oscillations the original conducting power was restored. Before the needle takes up the stable position, a scratching sound is heard when the telephone receiver is placed to the ear. One of the beauties about this form of wave detector is that its action can be made manifest to our senses in two ways—namely, by sight as well as by sound; for with the telephone receiver at the ear and the eye placed at the microscope, the action may be observed in a wonderful manner. In Dr. Forest's opinion, "The action is one of electrolysis by Hertzian oscillations and the local current." When the battery current is at first applied, infinitesimal particles are seen to be torn from the anode, and, floating across to the cathode, are the carriers of the current. Sometimes bridges of these particles are built up apparently by cohesive forces, and observations of the galvanometer needle show that the resistance is gradually decreasing, until one of the bridges has been formed across the gap. If at this point an oscillatory discharge of electricity is produced in the neighborhood, the increase of current, by producing electrolysis, generates bubbles of hydrogen gas, and these soon break asunder the bridges, and so increase the resistance. This process repeating itself, the local current forming the bridges, the oscillations breaking them by means of the hydrogen gas; this gas is not only in evidence in twice the volume of oxygen, but the latter usually forms an oxide with the metal, and so rupture of the bridges usually occurs at the cathode. Dr. Forest also assumes that the bridges never come into actual contact with the anode, but that a film of moisture almost of molecular thickness is interposed, but easily electrolyzed by a sudden increase of current; this increase, by producing oxygen, insulates the anode from the bridge, and so increases the resistance. These were the results of the preliminary investigations, but they have to be modified to allow of comparison with the electrolytic detectors. In the previous experiments we have seen that the gap was exceedingly small, and that conduction was produced by metallic bridges, the Hertzian oscillation assisting the increase of the resistance, whereas in all forms of coherer, from our definition, the oscillations produce a decrease of resistance; apparatus, therefore, which show an increase are properly called responders. When however, the electrodes are separated beyond a certain limit, polarization is found to take place, whether the material on either side of the gap be of the same or of different metals. When the local current is applied to the metallic surface, ordinary electrolysis takes place, the resistance of the little cell being small; but polarization soon sets in, and the local current is reduced to zero. This counter-E.M.F. is, of course, due to the layers of gas deposited on the electrodes of the cell or detector. Therefore, unless some stimulus is used to destroy the E.M.F. of polarization, the local E.M.F. must be above that critical voltage required for the decomposition of the electrolyte. The stimulus is found in the electric oscillations, and if the cell be placed in proximity to a Hertz oscillator, complete suppression of the polarization is observed, and the current is again allowed to flow. Here, then, we have true coherer action.

Lately another German investigator has discovered what he has since termed polarization cells, whose action is similar to that already described, and is obtained by using a Wollaston wire, which enables the anode to be obtained of a thickness comparable with that of the metal tentacles formed between the gap of the two silvered surfaces. In Dr. Forest's experiments, a Wollaston wire also was used, so as to obtain an immersed surface of the order of one-millionth of a square inch. Therefore, if the recovery of the high resistance is due to the polarization of the small electrode, and if from any cause the electrode should be depolarized, repolarization will be very rapid, and the current required to produce the small amount of oxygen will be very small. As we have seen, the theory rests on the assumption that the local current, by electrolysis, produces an E.M.F. of polarization, which, counteracting the local E.M.F., enormously increases the resistance; but oscillations produced from a Hertz oscillator completely annul the polarization, and allow the current to flow again; the process being repeated so long as the oscillations are in evidence. On what basis, then, does this assumption of polarization depend; and can it be shown that if polarization is suppressed the coherer action does not come into effect? The experiments carried out by Dr. Lee de Forest to prove this are very exhaustive, and seem entirely to

corroborate his views. In one experiment the Wollaston was replaced by a platinum wire, so adjusted that it just touched the surface of the electrolyte, which was at first alkaline, and afterward acid. In both cases it was found that a fairly good response to the electrical oscillations could be obtained. The platinum wire was then replaced by an iron one, and immersed in dilute sulphuric acid; no response was obtained, even with very strongly received oscillations. On looking for the explanation to these results, we see that the platinum would be affected most by the oscillations, since platinum is very easily polarized by a film of gas, whereas in the case of the iron, polarization is never allowed to take place, for as fast as the oxygen is liberated at the anode it forms an oxide with the iron, and this immediately dissolving in the liquid, ferrous sulphate is obtained. Other experiments were then performed by coating platinum with platinum black, which prevents polarization taking place. From the polarization hypothesis we should expect that in this case no response would be obtained, and experiment confirms this. Everything seems to point to the conclusion that polarization is necessary; but the depolarization must not be effected by the electrode itself, as in the case of the iron, but by the electric oscillation.

We shall now conclude with a short description of one or two of the coherers used at the present day in wireless telegraphy. The one devised by F. J. Smith may be taken as typical of carbon coherers. The carbon used is powdered arc-lamp carbon, which is placed in a thin glass tube furnished with terminals for connecting the coherer to the local battery. The terminals of this detector are furnished with points, and by means of a screw they may be enveloped in the carbon particles to any required depth. It is found that the best results are obtained by so adjusting the terminals that a small current is allowed to flow, and when this is done the coherer is very sensitive to the slightest electrical disturbances. Prof. Bose's form of coherer consists of a number of steel springs placed in a block of ebonite, which has a rectangular groove cut in it. The steel springs, which are in the form of a spiral 0.4 centimeter long, and of No. 34 S.W.G. wire, are prevented from falling out of the groove by means of a glass plate. The undermost spiral rests on a brass plate connected to a terminal which passes through the ebonite, while another brass plate is placed over the top spiral and is held in place by means of a screw. The coherer, on being connected in series with a battery and a sensitive galvanometer, prevents any current from passing when the spirals are in a loose condition; but when the spirals are compressed by the screw, which bears on the top plate, the apparatus is in a very sensitive condition, and if exposed to electric oscillations, its resistance, as shown by the galvanometer deflection, will have decreased enormously. Decoherence is produced by tapping or by turning back the screw. This coherer has been found to be more sensitive for a certain E.M.F. acting in the circuit, which must be found experimentally for each coherer.

The coherer devised by the Allgemeine Elektricitäts-Gesellschaft consists of a vacuum tube, into which is placed some metallic powder, lying between two silver stoppers in the narrow portion of the tube. The vacuum is used in order that the powder may be protected from the oxidizing effect of the atmosphere, and also to insure that no moisture ever collects on the powder. The inner faces of the stoppers are not parallel, and the reason of this is that varying degrees of sensibility can be obtained according to the position of tube. For it will be obvious that the cross-section of the powder, which does not entirely fill the space, will be greatest when the powder level is at its maximum—that is to say, when the narrow part of the space is the lower. On the other hand, when the wide part is the lower, the powder, of course, does not rise to the same level as previously, and the distance through the powder between the stoppers is at its greatest value, or, in other words, the resistance is at a maximum. In the first case the coherer is in position for greatest sensitiveness, while, in the second case, the position gives the minimum sensitiveness. It is almost unnecessary to point out that any degree of sensitiveness between the two limits can be obtained with this coherer. In Marconi's coherer the metallic powder used is a mixture of hard nickel and silver, of which a thickness of a few millimeters is placed between two silver blocks. Connection with these blocks is by means of platinum wires, which pass through the tube. Like all modern metallic powder coherers, a vacuum is made in the containing tube to protect the powder from oxidizing effects.—English Mechanic and World of Science.



A HOME-MADE ALTERNATING-CURRENT DYNAMO.

HOW TO BUILD A SMALL ALTERNATING-CURRENT DYNAMO WITHOUT CASTINGS.

By NEVIL MONROE HOPKINS.

NUMEROUS small books have been published on dynamo building, but they have been mainly devoted to descriptions of direct current generators. The little machine described in the following article produces a "single-phase" alternating current at 110 volts pressure, and is built without patterns and castings. The making of small dynamos is frequently given up by amateurs because patterns and castings are required. Patterns are often troublesome and expensive to make, and iron castings are not always procurable in the average town. The iron ring which forms the frame or body of the alternator described in this connection can be quickly made by almost any blacksmith, and is to be preferred to a casting if made from good soft iron. For a larger dynamo than the one described the iron ring can be very easily made by using blacksmith's rollers, known as tire benders. The little machine, when its field magnets are only feebly excited, generates the most approved kind of alternating current for medical purposes, as the voltage is steady; consequently furnishing a current which is free from the jerking or twitching sensation so common with the use of induction coils. With the fields strongly magnetized the machine, when run at about 2,000 revolutions per minute, is capable of lighting a 50-candle-power 110-volt lamp. As the designing of alternate current dynamos, mathematically considered, is rather beyond the average amateur, the author merely gives the result of calculations, except in the matter of field magnet winding, where a choice of wire presents itself, in order that the field magnets

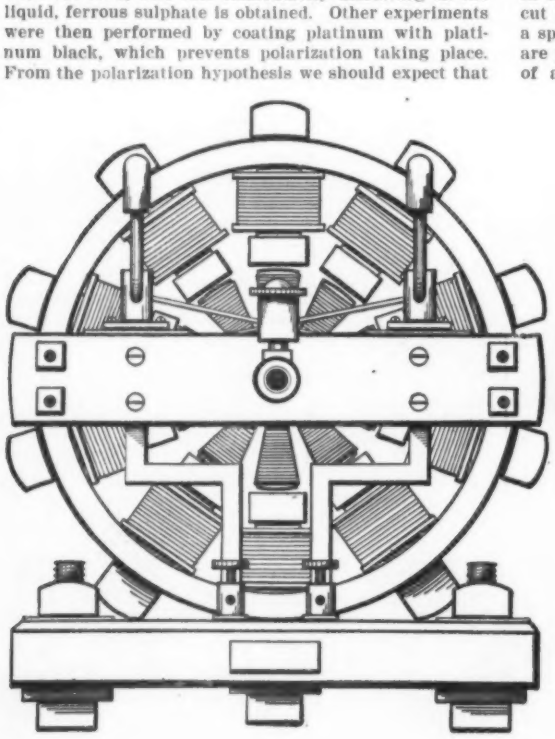


FIG. 1.

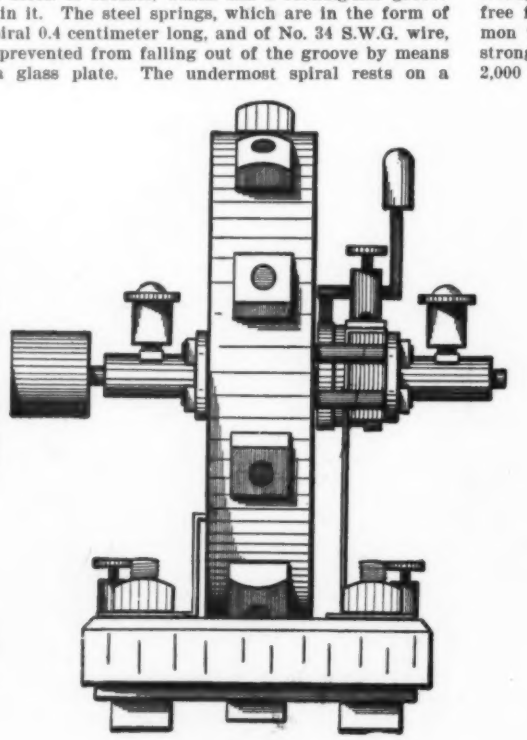


FIG. 2.

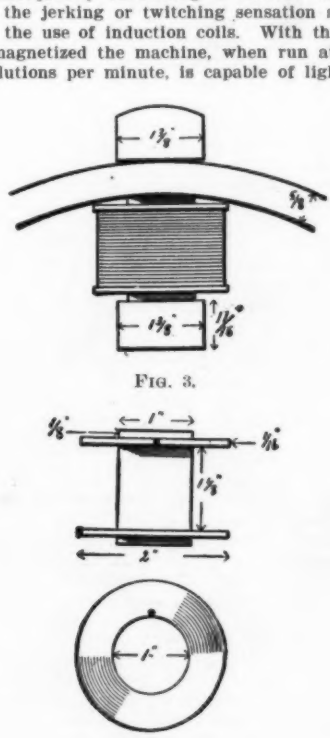


FIG. 3.

FIG. 4.

made shall be suitable for any exciting current at the command of the user. The mathematical designing of alternator armatures would take up more space than our limits allow. The armature as described is readily detachable from the shaft and collector rings, leaving an excellent field for experimentation with different types of armature cores and windings.

The electrical engineer whose knowledge becomes deficient when he leaves direct current dynamo ma-

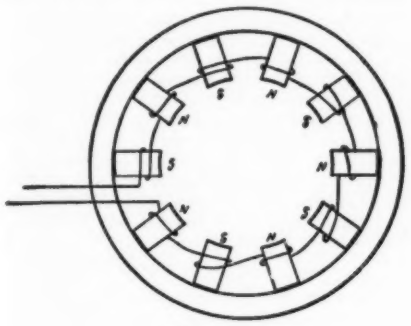


FIG. 5.

chinery and deals with generators of alternating type has a very limited field for practice, as the alternating current machine has come to the front to remain, displacing the direct current generator in many important branches of electrical engineering. There are to-day many electrical men who are at home, so to speak, when dealing with the applications of current electricity, and are badly at sea when they meet with problems pertaining to alternating currents. The alternator we are about to build is the simplest form at present in actual use, being excited by a battery, or other source of direct current, and delivering, in place of the mechanical power required to drive it, an alternating current, known as a "single phase." Alternators are built for lighting and power transmission, both "single phase" and "polyphase," although the "polyphase" generators are principally employed for power transmission. In the alternating current dynamo the voltage rises and falls in a very rapid periodic man-

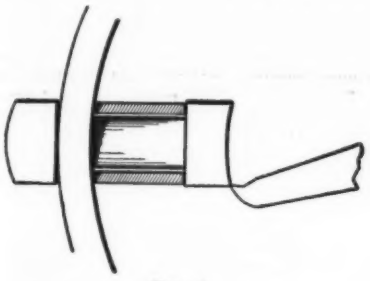


FIG. 6.

ner, driving a wave of electricity first in one direction, then in the reverse, with great rapidity. The field magnets can be considered entirely apart from the armature in a separately excited machine, whether the armature is of the tooth type or ring type. The only relation which we need consider in the machine which we are building is in the number of field magnets. If we use ten field magnets and consequently ten poles, we must make the armature with ten teeth, if of the tooth type; or, should we make a ring armature, the ring must be wound with ten coils equidistant. The armature given is the tooth type, but is conveniently removed, leaving the shaft and hub to receive a ring armature, with the collector rings ready to be connected to the new and differently designed armature. The term "period" used in connection with an alternator denotes the time elapsing between one

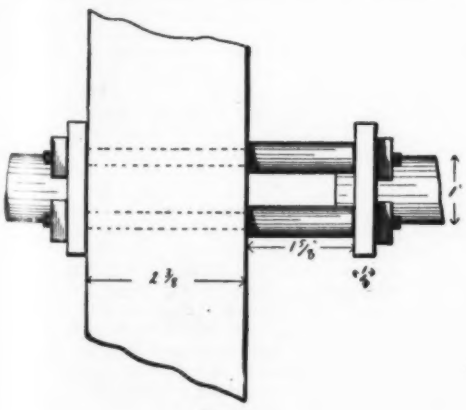


FIG. 7.

complete reversal of the current. The "frequency" is the number of double reversals of the current per second. The frequency varies in practice between 150 and 25. It will be readily seen that the greater the number of poles and the greater the speed at which the machine is driven, the greater will be the frequency. Alternators are invariably designed with more pole pieces than direct current machines, in order to get the required number of reversals of the current every second. If the frequency is not high enough, lamps, for instance, in circuit, would flicker. If only two or four poles were employed in our alternator, the armature would have to revolve at a dangerously high speed to obtain the required frequency. The number of pole pieces for alternators varies from six to one hundred and over. The largest slow speed machines which are designed for direct connection to the driving engine have over one hundred poles. Alternators for commercial use are usually designed to give a voltage between 1,000 and 3,000. This high voltage is desirable for power transmission at great distances, whether for lighting or motor work. By the use of transformers immersed in oil for high insulation, the voltage is conveniently "stepped up" to 30,000 and power transmitted one hundred miles, and "stepped down" by transformers to any voltage desired. The transformations of current and voltage without altering the actual value, or electrical horse power, are very beautiful. For example, if we have at hand 25 amperes at 2,000 volts tension, or pressure, we may exchange the 2,000 volts for more amperes and *vice versa* without altering the power to do work, which is the definition of energy. An armature could, of course, be wound to produce a current at 20,000 volts, but the all-important electrical term "insulation"

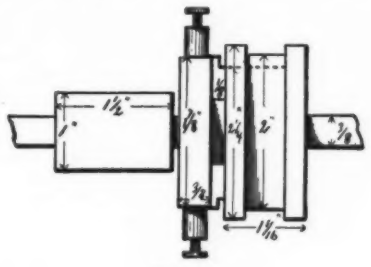


FIG. 9.

would forbid it. Assuming the machine were wound for 20,000 volts, the amperage would only be 2.5. Again, should an accident happen to the transformer insulation, when under the tension of 20,000 volts, the primary and secondary windings might come together, which would throw the alternator in danger. The writer recently had charge of an insulator testing plant with alternator and transformers in combination, giving a voltage at times as high as 50,000. While the alternator laid down in the following description is rather small for very high voltage, it will be found very convenient for illustrating principles, and if successfully built, one twice the size will be all that is required to furnish light and power for commercial purposes.

THE RING AND FIELD MAGNETS.

It would perhaps be wise for the beginner to con-

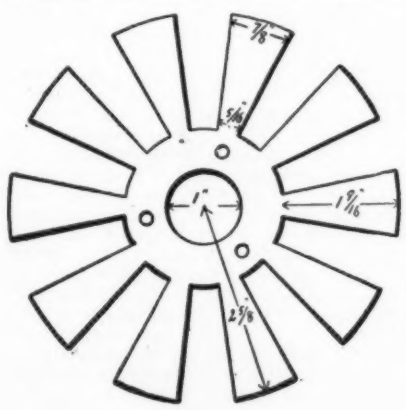


FIG. 10.

struct the machine according to the directions and dimensions laid down before undertaking to build one on a much larger scale. The size of the largest generator it is feasible to put together on this system is somewhat limited by the largest bolts with the proper heads, and the heaviest and widest tire it is possible to bend with rollers, but it will be seen that a powerful and useful dynamo can be quickly built on this plan and at a reasonable cost. For experimentation with armature cores and windings, the ten-inch ring machine will be of great assistance. Let us begin by forming the iron ring and mounting the field magnets. This ring should be about ⅝ inch thick and 2¾ inches wide, with an internal diameter of 10 inches. It can be started by using tire benders, but, owing to its

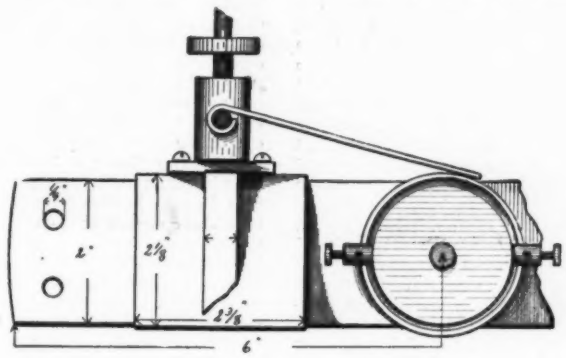


FIG. 8.

small diameter, it must be helped out, so to speak, by manipulation on the mandrel and afterward welded. After hammering the ring as near a perfect circle as possible, it should be chucked on the lathe and turned perfectly true outside and inside as well as on the edges. The ring should now be carefully marked off in ten equal divisions and holes drilled radially on each mark to receive the iron bolts. Each bolt must measure 3½ inches in length from the face of the bolt head to the top of the screw. The holes must be just large enough to allow the bolts to be hammered in through the ring, as a tight fit is very desirable. By referring

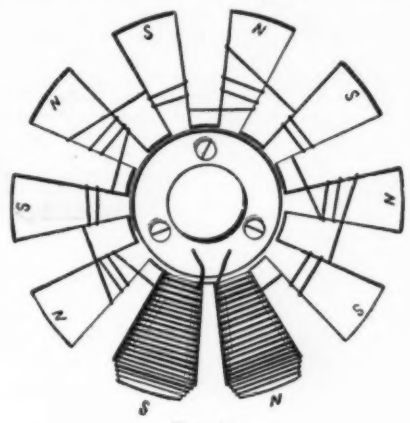


FIG. 11.

to Fig. 3 the size of the bolt head can be seen. If the head of the bolt were larger the field would not be as efficient, as magnetic lines of force would leak too freely from pole to pole, instead of making the circuit through the armature core.

Having secured the bolts and drilled the holes to receive them, the next operation is the making of the magnet spools. These must be made from brass, as they are to answer the double purpose of holding the magnet wire and of taking up the pressure when the screws are firmly turned in place on the bolts. The dimensions of the spools are clearly shown in Fig. 4. Brass disks 2 inches in diameter are mounted and soldered on to pieces of brass tube 1½ inches long, leaving ⅛ inch top and bottom to take the pressure

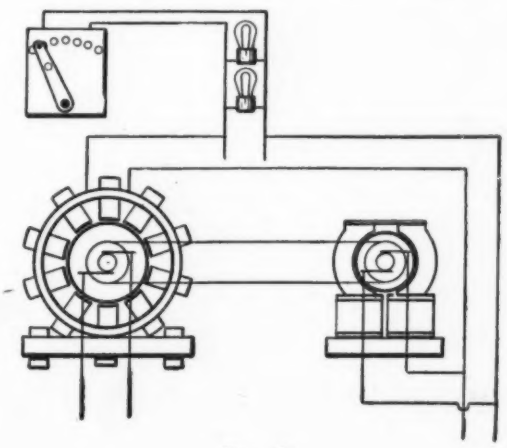


FIG. 12.

off the wire and ends of the bobbin when the whole is clamped firmly in place. This space between the head of the bobbin and the head of the bolt also allows the wire to come through and make connection with the next without having the insulation crushed. These disks, which form the ends of the bobbin or spool, can be turned five or ten at a time on the lathe by soldering together at the edges the required number of

square pieces of brass and chucking in the lathe in order to cut the one-inch hole through the center. Of course, after the hole is made the disks are mounted on a lathe mandrel and the corners and solder turned down until the disks measure 2 inches in diameter. Having made the ten brass bobbins, they should be given five or six coats of shellac, after small holes have been drilled in the disks to carry the wire out of the bobbin. Each coat of shellac should be allowed to harden before the next coat is applied, and the smallest size of rubber tubing should protect the wire where it passes through the hole. The spools should be slipped over the bolts to see that they go up well against the head. Should any of them stick before they go all the way on, the bobbin should be chucked in the lathe and one end of the tube quickly reamed out until the bobbin will easily slip up as far as the end of the bolt head. Of course, the best way to wind the bobbins is to chuck them in the lathe. Here a choice of wire is to be made. Each bolt must be wound so it can readily be made a powerful magnet without requiring a very great current strength. To powerfully magnetize one of the iron bolts used in the alternator 600 ampere turns will be required. We may get the required number of magnetic lines of force in our bolts by using any of the following windings and currents. If we wind each bolt with 50 turns and employ a current of 12 amperes, it will amount to 600 ampere turns, as well as the following: Six amperes and 100 turns; 3 amperes and 200 turns. As we expect to use our dynamo in connection with a fan motor for medical purposes, it would be well to select a winding that would be the most economical when connected through lamps to a 110-volt service. We will go still farther and wind each bolt with 300 turns of wire, requiring only 1½ amperes to bring the field up to a powerful state of excitation. With this winding, when the generator is to be used in medical treatment only, ½ ampere will be required to send around the field. Each spool will hold 300 turns of No. 20 double cotton-covered magnet wire, if the wire is carefully and neatly wound on. This size of wire will go on the bobbins in 12 layers and measure 120 feet for each spool, 1,200 feet for the ten. The voltage generated in the armature will vary with a constant strength of field, with the speed at which the generator is driven giving another method for regulation. For medical treatment currents of varying character may be had by using the dynamo as follows: First, by giving the fields strong excitation and driving the machine at a low rate of speed. This will give ample voltage and current, but at a low frequency of alterations. Secondly, the fields can be only very feebly excited and the machine driven at the highest speed possible with the motor at hand. This will give the required voltage and current also, but the frequency will be extremely high. Never take the current when the fields are strongly excited and the machine is being driven at a high rate of speed, too, for this current and voltage are only intended for lighting and experimental purposes.

Having wound and mounted the field bobbins and screwed the field bolts firmly in place, the free ends of the wire should be joined by means of small brass screw sleeves known as connectors. The ends must be connected up so the current will go around one spool in one direction and around its neighbor in the reverse, in order to get north and south poles. By referring to Fig. 5 the idea will be understood. Having connected according to the diagram the polarity should in all cases be tested by exploring the field with a compass needle, to make perfectly sure the poles alternate in polarity all the way around the ring. Should this connecting be neglected, no alternating current will result. In testing the fields with the compass needle, the fields had better be excited with a battery, if at hand; otherwise the spools can be connected to the 110-volt mains, but in each and every case with a 110-volt lamp in series with the field. Should the field winding ever be connected directly with the 110-volt circuit, an accident would surely result. The fuses in the building should blow out, but, in case they failed, the wire on our machine would have to blow out instead. The ring should now be mounted on its base board. This had better be made from oak and be one-half inch thick. Figs. 1 and 2 show the method of making feet for the base, by using bolts and nuts like the ones used on the fields. Heavy pieces of iron should be bolted across the grain on the bottom of the base board to prevent it from warping or buckling in any way, as well as to add weight to the base. The base measures 8 by 12 inches. One of the bolts, namely, the bottom one in the ring, is substituted for a longer one, capable of going through bobbin, ring, and base board, carrying an iron washer and having its bolt head screwed on firmly.

It will be noticed how conveniently the two adjacent bolt nuts come in position against the oak base, being forced in the wood a little way, when the lower bolt is strongly turned with a wrench. These serve to keep the dynamo straight on the base and prevent wabbling or turning. Brass binding posts must now be mounted on the base and connected with the two free ends of the field winding, a second pair being mounted on the base in front to be connected to the brush holders, collector rings, and armature. Before painting the ring and bolts, the ring must have four holes drilled through the edge to receive the bolts which carry the bearing cross pieces, brushes, armature, etc. These holes must be most carefully marked off, for the bearings, when mounted, must be exactly in the center of the ring and pole pieces, or else it is very evident that the armature will not revolve freely, but collide with the pole pieces. To lay off the marks for these important holes, the ring should be marked off exactly in half, by measuring with mechanic's dividers. Having proved that you have found the exact center of the ring, by the most careful measurements, a tiny hole should be made to mark the place, a similar hole marking the spot on the opposite side of the ring on the same surface. The four holes which are to carry the bolts go through the ring on each side of the marks exactly one-half inch from them, top and bottom. In drilling these holes do not attempt to drill all the way through from one side, but reverse the ring and carefully carry the marks around to the other side and go through and meet the partially completed hole. Should this not be done, the drill will surely travel a little out of the line intended for it, and trouble will surely result. The ring and bolts will have a good appearance if painted with black bicycle enamel, looking very well in combination with the brass trimmings. The base board should be given four or five coats of orange shellac, applying it top as well as bottom, in order to keep out all dampness and prevent warping tendency. The bolt heads can to advantage be cut out a little on the lathe as illustrated in Fig. 6. This will add to the efficiency of the generator for lighting and experimental purposes but is not absolutely necessary for medical purposes. Should a larger machine be constructed, the writer would advise the cutting out as shown. As will be readily seen, the iron bolt is passed through a piece of heavy iron pipe the exact length of the brass tube in the bobbin. The iron pipe should be as large as possible, in order to better take up the heavy strain due to the tool cutting in the lathe. They had perhaps better be all cut at the same time, using ten pieces of the pipe slipped on in the place of the bobbins. The armature described in this connection is intended for the simple smooth bolt heads, and must be cut a trifle larger than the one in the diagram if the bolt heads are to be cut out in the lathe. In cutting the bolt heads it will be evident to every mechanic that light cuts must be made, in view of the manner the work is held. Be sure each bolt head is turned perfectly square before cutting out, or the resulting curved cut will be everything but attractive in appearance.

THE BEARINGS AND COLLECTOR RINGS.

The machine is now ready for the bearings, the cross pieces which support them, and the collector rings. Figs. 7 and 8 show the dimensions and enlarged portions of the bearing supports. Bolts 5½ inches long are driven through the holes in the ring, leaving just enough room on the back to go through the rear bearing plate, so it may be bolted securely in place. Four brass tubes carefully cut to measure 1⅝ inches are put on the bolts in front and the second bearing support firmly clamped against them. Fig. 7 shows plainly the principle. The bearings are to be next made from solid brass rod and bored through on the lathe. Brass rod one inch in diameter is cut in two pieces 2½ inches long each and a ⅜-inch hole bored through on the lathe. The bearing plates are now taken off and placed in the lathe, in order to cut an inch hole through to receive the bearing. The bearings are to be soldered or brazed to the plates. As it is of utmost importance that the bearings should be "in line," they must not be soldered to the plates until the shaft is put through, throwing the bearings in perfect line. Should this be overlooked and the soldering or brazing be done, the chances are that the shaft would not go through the bearings at all, or else turn with a cutting and binding resistance. Having mounted the bearings to satisfaction, they can be bored through on top in order to receive small brass oil cups, which come ready made of just the size required. They can be screwed right on the bearing and are as useful as ornamental. The wooden hub which supports the collecting rings can now be made and is illustrated in Fig. 9. It is best turned from hard wood, and, being of the form shown, enables one to readily detach the armature from the shaft. The sliding rings are easily made by sawing off the end of a piece of large seamless brass or copper tubing. The rings are smoothed down with a file and driven on each side of the hub, which must be turned on the lathe to receive them and make a good, tight fit. The binding posts are screwed in the flange turned for the purpose and are connected to the rings as illustrated. The wires had better be soldered to the rings as well as to the binding posts, to insure a perfect electrical contact and prevent their working loose when the armature is driven at the high speed of two thousand revolutions per minute. The hub shown on the extreme left of the shaft is of brass and is designed to carry the armature. The shaft is to be cut from a piece of ⅝-inch steel machine shafting. The brass and wooden hubs should go tightly on the shaft, using a mallet if necessary to drive the shaft through. Small washers will in all probability be found necessary, as no lateral movement of the shaft, armature, and collector rings is desirable. The front bearing plate is now ready to be drilled to receive the little screws which support the blocks which mount the brushes and their supports. The dimension and position of the blocks are clearly shown in Fig. 8. They should be about an inch thick and have several coats of orange shellac. The brush holders are easily made from large binding posts and heavy brass wire bent at right angles where the end goes through the binding post. With a combination of a binding post and heavy wire bent as illustrated, a varying pressure of the brushes on the collector rings can be had by simply moving the long arm of the wire back and forth, or the brushes may be raised from the rings altogether, which is a very desirable thing. The connection between the brush posts and the binding posts on the front of the base is best made by using copper ribbon about ½ inch in width. The ribbon is cut and soldered together again at right angles when a change in direction is necessary. The use of copper ribbon gives a much neater appearance to the generator than connections of wire, and is to be seen on most fine dynamos. A pulley can now be turned from hard wood and have a diameter of about 2 inches and be about 2 inches in length. A couple of layers of lineman's insulating tape wound around the pulley in even layers makes the most excellent surface for the belt to run on, as there is the proper friction for the belt, and the cushion formed adds to the machine's easy and noiseless running. The brass work, if polished with the finest emery cloth, had better be protected with lacquer if the machine is to be ornamental as well as useful. Little handles of hard wood are to be turned to go on the long end of the brush rockers and be lacquered. This brings the machine to the armature, and another choice in type or construction presents itself.

THE ARMATURE.

Either a ring or toothed armature will give good results with the field just built, if only very thin soft iron is allowed to enter into the construction. The author will give only one type of armature completely worked out, and has selected the tooth type because, on the whole, it will be found the easiest to make, and prove, perhaps, a little more efficient, because the grade of Russia iron that comes in sheets is softer than the band iron used in the construction of the ring type of armature. If, after completing the toothed armature, the builder cares to experiment with a ring type, no great difficulty will be met, if band iron is procurable that has not been bent every few feet, as this seems to be the custom in packing band iron for shipment, etc. If the iron cannot be had without these sharp bends, it can be hammered out fairly well and made to answer the purpose. The band iron should be about one inch wide and as thin as possible. A wooden block should be turned in the lathe to form a drum to wind the iron on and be such a size that the iron, when wound on about ⅝ inch thick, will revolve in the field, clearing the pole pieces by ¼ inch. The iron should be bound with small iron wire and, after giving a coat of shellac, be wound with insulation tape. The ring must be wound with ten coils of wire equidistant, each coil having a reverse direction from its neighbor. One drawback in making an armature of this type is the mounting of it on the shaft, but this can be accomplished fairly well for experimental purposes by using a turned wooden hub and mounting that. By referring to Fig. 10 the toothed type of armature can be seen. The core for this armature is made by cutting out single pieces from the thinnest Russia iron, about 60 sheets to the inch. Thirty pieces will be all we require for the present type. Copy the diagram exactly by cutting with tinner's shears, all but the center hole, which is cut afterward on the lathe. Cut out the first toothed disk very carefully, for this is to be the guiding pattern for the rest. An easy method of getting out the remainder of the disks is as follows: Cut 30 small pieces, preferably squares, from the sheet iron just large enough to make one disk, and put one disk at a time in the screw vise under the carefully cut iron pattern. It will be found a very easy method if a good sharp pair of tinner's shears are to be had. The chief care necessary is in turning the pattern and half cut blank around in the vise in order to get at the rest of the teeth. If the different disks are laid on top of each other as they were cut, no difficulty in making a smooth and symmetrical armature core will be met. That is to say, a tooth on a disk, cut from a given tooth on the pattern, should be laid on its neighbor's which was also cut from the same tooth on the pattern. This is important and must not be overlooked. The core is now ready to receive shellac. Each disk must have a coat, and a piece of tissue paper pressed on before it has become hard, before the disks are permanently put together. Two iron washers must be placed on each side of the core to act as cheeks and stiffen the pack of disks when the whole is bolted together. Fig. 11 shows one of the iron washers in place. Having placed the disks and washers as evenly as possible, they should be firmly clamped in an iron machinist's vise and the holes for the bolts put through. After bolting together and screwing up as tightly as possible, the core must again be placed in the vise and all unevenness smoothed down with a flat file. The core is now ready to have the hole cut through the center by chucking the core by the ends of the teeth in the lathe. The core must be perfectly centered, and all usual centering tests must be made before a single cut in the center is made. Use a sharp tool and cut out a one-inch hole through the cheeks and disks.

The core must now be mounted on a lathe mandrel and the edges of the iron washers turned up true. The ends of the teeth are too thin to stand the strain of cutting or truing in the lathe, and must be carefully made of equal length by filing with a flat and fine file. The armature should not be cut away on the teeth any more than possible, as the nearer the ends of the teeth approach the field poles, the more efficient will be the machine. A keyway is made in the brass hub by chucking in a metal planer, if possible to have the use of one. The keyway in the hub to receive the locking key is easily made with the file. The core is now given five or six coats of shellac, each coat being allowed to thoroughly harden before the next coat is applied. This is a matter of extreme importance, as a

poorly insulated armature is worse than none at all. Just before the last coat of shellac becomes set, each tooth of the core is covered with heavy pieces of cotton or silk remnants. This is also very necessary in order to keep the insulation of the wire away from the sharp turn made at the edge of each tooth. This silk covering is given a final coat of shellac before the operation of winding on the wire begins. Wind on the wire carefully and neatly as follows: Commencing from the bottom of any tooth on the core, wind No. 22 double cotton wrapped magnet wire on in four even layers. Each layer must be closely wound and a coat of shellac applied between each layer. Having completed one tooth, its neighbor must be wound in the reverse direction as illustrated in Fig. 11. No bobbins or spools are necessary to hold the wire on this core, as the shellac, after hardening, is all that is necessary to keep everything in place. The shape of the teeth, in addition, tends to keep the wire in place, and will prevent its flying off when under the centrifugal strain Each layer on a given tooth is a trifle shorter than the one under it. The reason is obvious, not to speak of the neat appearance it gives. When the winding is completed, give the whole three or four coats of shellac and do not test the armature under high speed until the shellac has become perfectly hard in every sense of the term. The author had the misfortune to try the armature when the shellac was nearly hard, and, on stopping the machine, found long needles of shellac that had made their way to the surface oozing out in all directions. This armature when in condition to run without disturbing the shellac will be found efficient for lighting lamps and for furnishing a delightfully even and, if one may say, smooth current for the treatment of patients. It is hardly necessary to point out the connections between the two free ends of the armature and the collector rings before going to the method of connecting the generator to the electric lighting mains. Fig. 12 illustrates the plan of connections. As each lamp is added between the mains the field of the generator becomes more strongly magnetic. For some cases where the machine is desired for medical use the current delivered when one lamp is in circuit will be too strong. This represents a current strength of about one-half ampere going around the fields. If two lamps are put in series across the mains and connected with the fields, a much weaker current will be delivered from the machine. If a rheostat is introduced into the field circuit having a greater resistance than several lamps as a maximum, the current from the generator can be regulated to a nicety. There is absolutely no danger of the current from the electric lighting circuit getting into the armature of the generator and doing any damage to patients, but it must be remembered that the generator just completed is capable of shaking one up just as effectually as the main line, if a strong field and a high speed are put in combination.

CHEMICAL SOLUBILITY.

By Dr. O. N. WITT.

HE who has learned to observe the things about him, and has once enjoyed the satisfaction that comes from comprehending and intelligently studying the processes of nature, finds himself irresistibly urged forward still further along the path of investigation and continually involved in new problems, the solution of which is a pleasure, even though he learns in the fullness of time that the very questions that he has put to nature have been asked and answered before. For to the great majority of mankind the possession of knowledge gives less pleasure than its acquisition.

In the course of our study, however, there always comes a time when we discover that the limits to which the observation of nature may be pushed are very different for different methods of observation. Observation, strictly so called, does not carry us very far, for its scope is restricted by the limitations of our senses. We can see that horses run, birds fly, and treetops are tossed by the wind; we can smell the fragrance of roses; we can estimate the hardness and weight of stones by the sense of touch. But every child knows that all these phenomena, which we can follow with our senses, are accompanied by others, which cannot be thus directly perceived. A rose seems to be motionless and unchangeable. Not until we compare its present appearance with its former image, preserved in our memory, do we become conscious of the fact that a change has taken place, that the full blossom of to-day has replaced the closed bud of a few days ago and the green shoot of a still earlier epoch. And not until we have impressed the sights of to-day, in their turn, on our memory and then preserved them through days and weeks shall we be able to include the withering of the rose and the formation of the hip, or seed-pod, as additional links in the chain of phenomena. We know, however, that there has been in nature no abrupt substitution of one image for another, but a continuous process of gradual transformation, and that it is the slowness of this process that makes it appear to us as a discontinuous series of isolated phenomena.

There are other processes of a directly opposite character, inasmuch as they are too rapid for our senses to follow them. A cannon is fired before our eyes. We see a flash, hear a report, and instantly note the hole made by the ball in the distant target. What lies between must be bridged by inductive reasoning, unless we choose to employ the modern means of investigation, by which science has proved that we did not err in assuming that the ball which we saw placed in the cannon has flown through the air to the target so rapidly that our eyes could not perceive it.

We are so accustomed, in observations of every character, to supply by inductive reasoning the stages of the process of which our senses give us no direct perception, that we have almost ceased to make any discrimination between the two kinds of observation. And yet the distinction must be made if we wish to understand the reason why absolutely no limit can be set to the material which is obtained by observation and serves as foundation for the progressive enlargement of knowledge. So long as we are dependent upon our unaided senses, we can assign perfectly definite limits to their testimony, but as soon as we are able to call in the aid of inductive reasoning, we find this ever growing bolder, and leaping wider gaps, the more experience we have in the application of this method and the greater the material at our disposal in the form of analogous cases which may be used for comparison.

Through such an extension of the limits of our powers of observation it may come to pass that certain ideas, which seem to be perfectly fixed in speed, undergo a change in the course of time. I shall not now discuss the oft-quoted change in the meanings attached to the words "quick" and "slow," "large" and "small," but will adduce, as an example, a word which appears, at first glance, much less elastic than these.

It might be assumed that designations from which all idea of relativity is excluded *ab initio*, for example, the words "soluble" and "insoluble," could never be subject to any change in definition. When a solid is brought into contact with a liquid, there would appear to be, logically, but two possibilities. Either the solid in question will be diminished in mass by the solution of a portion of it in the liquid, from which it can be recovered by appropriate methods, or it will show no change whatever, even after prolonged contact with the liquid. In the former case we should call the solid soluble; in the latter insoluble.

But if we make many experiments of this sort, we cannot fail to observe notable differences in solubility. If we restrict ourselves to the consideration of the commonest solvent, water, we find that this dissolves many substances very quickly and in large quantities, and others very slowly, in respect to actual speed of solution, though in many cases the point of "saturation" is soon reached.

The study of the phenomena of solution soon brought the conviction that the two concepts of solubility and insolubility will not suffice, and led to the introduction of a third, relative concept, that of resistance to solution (Schwerlöslichkeit). From this moment the narrow limits of observations of solubility fell away, and the field was infinitely extended by the study of resistance to solution and its limits.

A few examples will illustrate more clearly the significance of the theory which I am here attempting to develop.

The average housemaid recognizes only solubility and insolubility. She knows that she must not wash the sugar figures of the confectioner because sugar is soluble, but she is quite as firmly convinced that she may wash a plaster of Paris figure as much as she pleases, because she regards it as insoluble. On the other hand, every mason's apprentice knows that, though plaster is very difficult of solution, it is by no means insoluble. Therefore, though he does not hesitate to make plaster ornaments for inside walls and ceilings, and even to wash them thoroughly when necessary, it would not occur to him to apply such ornaments to exterior walls, where the rain would soon wash them away to such an extent as to make their forms unrecognizable. Plaster of Paris, or gypsum, in fact, is very difficultly soluble. Not only does it require for its solution about 500,000 times its own weight of water, but it dissolves very slowly and only after long contact with water.

For the chemist, of course, these matters are of especial importance. He has long ceased to include gypsum even among difficultly soluble, not to speak of insoluble substances. For him insolubility begins much lower in the scale; his ideal in this respect is found in the noble metals, silver chloride and barium sulphate.

But very exact investigation shows that even the substances that the chemist regards as insoluble do not strictly deserve this name. Even with the most careful use a platinum dish shows a continuous loss of weight with the years. This fact proves that platinum cannot be absolutely insoluble in the liquids with which the dish comes into contact. Silver chloride is soluble in about 500,000, barium sulphate in about 400,000 times its weight of water.

From the above it is evident that, in the strictly scientific sense of the word, insolubility does not exist, but that even those substances which are characterized by the most obstinate resistance to the solvent action of water, may properly be designated merely as extraordinarily difficult of solution, not as insoluble. Such feeble solubility, however, cannot be detected directly by the eye, but can be proved, in many cases, only by very complicated methods and reasoning.

The preceding considerations might appear to be merely scientific subtleties, did not their great and far-reaching importance become evident in other fields of study.

Consider the mighty circulation of water on the earth's surface, that process to which alone the possibility of life on our planet is due. By the solar heat continually radiated to the earth, water is incessantly evaporated and raised to the upper strata of the atmosphere, whence it falls again in the forms of rain, snow, hail, and dew. The average annual precipitation for the whole earth may, with sufficient exactness, be taken as twenty-four inches. In other words, every square foot of the earth's surface is systematically watered and soaked, in the course of a year, with two cubic feet of water. Under such conditions how vast a quantity, even of the most difficultly soluble constituents of the earth's surface, must be continually dissolved and carried away by seepage water.

Under such conditions we cannot be surprised to find great deposits of very difficultly soluble substances which yet, as their whole structure proves, can have originated in no other way than through precipitation from aqueous solution. For the geologist and the mineralogist there is really no such thing as insolubility, and the reluctance to abandon the idea has, perhaps, done more than anything else to retard the comprehension of rock formation.

There is another field, that of agricultural chemistry, in which it is dangerous to employ the idea of insolubility. The nutrition of plants, the study of which was instigated by Liebig, and has since grown into a special branch of science, becomes intelligible only when we remember that even those substances which are commonly regarded as completely insoluble may serve as food for plants by being gradually dissolved in the soil. Mistakes are continually being made in this matter. Less than twenty years ago, when a new source of phosphates was provided by the Thomas process of making steel, it was thought necessary to convert the phosphates contained in the Thomas slag into a soluble form, in order to make them available for agricultural use. It was learned, later, that it is quite sufficient to distribute the slag through the soil in the form of a very fine powder, which does not resist the slow solvent action of water.

Finally, the importance of the part played by the gradual solvent effect of water in changing the appearance of art monuments and the surface of the earth itself, was explained in my recent articles on patina, and therefore needs no further mention here.

The foregoing remarks will suffice to show how greatly the field of our observation expands when we cease relying on unaided perceptions of sense, and begin to connect and interpret isolated observations by logical reasoning. We can follow with the eye the process of solution of a lump of sugar in water, but it is only when we invoke the aid of inductive methods that the field of our observations extends over periods of time in comparison with which the duration of a human life is insignificant, but nevertheless yields results as certain and unimpeachable as if we had perceived them with the eyes of the flesh.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT, from Prometheus.

CONTEMPORARY ELECTRICAL SCIENCE.*

MATTER AND ETHER.—J. H. Jeans discusses the legitimacy of applying the theorem of equipartition to a system consisting of both matter and ether, and traces the course of events when one or more masses of gas are left to themselves in undisturbed ether. The transfer of energy between the different degrees of freedom of the gas at any point is extremely rapid. The first phenomenon is that the energy of these degrees of freedom arranges itself according to Maxwell's law. The time required is the small fraction of a second. The next phenomenon is an equalization of temperature by conduction. Simultaneously with this, a transfer of energy is taking place between the principal degrees of freedom of the molecules and the vibrations of low frequency in the ether. This equalizes the temperature of different masses of gas, and endows the ether with a small amount of energy, equal to that of a finite number of molecules of the gas, but small compared with the total material energy. The time required for these phenomena must be measured in minutes, days, or centuries, according to the linear scale of the system. After this a third transfer of energy begins to show itself, but its rate must be reckoned in millions or billions of years unless the gas is very hot. It represents vibrations of high frequency. If the gas is in vacant space, the energy set free streams away into space, but if the whole system is inclosed in a perfectly reflecting boundary, the energy accumulates in the ether.—J. H. Jeans, Philosophical Magazine, July, 1905.

ELECTRIC MICROMETER.—A new micrometer of great range and accuracy has been designed by P. E. Shaw. It consists of a system of six massive levers, the final effect of which is to reduce the movement of a micrometer screw in the ratio of 1,000 : 1. Contact between the last lever and the object to be measured is made electrically, and the smallest distance which is distinctly measurable is 0.4 $\mu\mu$, a quantity of the order of the size of molecules. The short ends of the levers are fitted with hardened steel plates and with a metal casing which forms the sides of an oil bath. The long ends are fitted with pins which rest on the steel plates, and are partly submerged in the oil to reduce friction and catch dust particles. The electric contact surfaces are of iridio-platinum. The plate in contact with the micrometer screw is of agate. The instrument is inclosed in a felt-covered box, and is suspended by rubber springs from the top of a massive frame, which itself rests on a pile of heavy concrete slabs with rubber cushions at intervals. Contact is discovered by a telephone, the difference of potential being 0.01 volt, which produces a spark not more than 0.1 $\mu\mu$ long. Compared with other micrometers, the instrument is less portable than the optical lever and slower than the microscope, but 500 times more accurate than the latter and 10 times more accurate than the former or any interference method, besides having a much wider range, amounting to 10,000 units.—P. E. Shaw, paper read before the Royal Society, April 13, 1905.

* Compiled by E. E. Fournier d'Albe in the Electrician.

[Continued from SUPPLEMENT No. 1557, page 24945.]

IRON AND STEEL HULL STEAM VESSELS OF THE UNITED STATES.*

By J. H. MORRISON, Author of "History of American Steam Navigation."

NORTHWESTERN LAKES.

WHEN the first iron-hull vessel was built on the Northwestern Lakes, the wooden shipbuilders in that section gave but a passing notice to the innovation, thinking it but a fancy of the owner to have a vessel different from the prevailing type on the lakes. Another was built a few years later, and yet not much more consideration was given the subject, though it was known they were profitable vessels for their owners. A few years later and the construction was begun of four larger iron-hull steamers of an improved type for the lake service. Then it was the wooden-hull shipbuilders began to see the drift of opinion in favor of the iron hull, that was taking the same course as on the Atlantic coast. The war was now on, between the wooden hull that had held its own for so many years, and the iron hull that had demonstrated its superiority of a profitable vessel. The same arguments were used as in a similar case of construction on the coast, but it was no use after a few years, for the iron hull was silently and effectually gaining ground in the whole country.

But the wooden shipbuilders were not compelled to close their yards for several years for the want of orders, from the competition of the iron hull. What was the main factor in closing them at a later period to a great extent, was the scarcity of oak timber for building the vessels. The conditions that prevailed—that there were no large iron-hull steamers constructed on the lakes from 1873 to 1880, and that for a period of six years, from 1874 to 1879, there were built on the lakes thirty-three wooden-hull steam vessels of over 500 net tons each, aggregating 37,201 net tons, and

THE "ONOKO," 1882.

the largest 1,927 net tons—show the hold the wooden hull still had on the vessel owners of the lakes. Local conditions of shoal navigation no doubt had its effect. This consideration for the wooden hull continued almost to the opening of the steel era on the lakes.

On the Northern Lakes iron shipbuilding was first brought into practice by David Bell, of Buffalo, N. Y., in the construction of the screw-steamer "Merchant" in 1861 for J. C. & E. T. Evans, of Buffalo, for lake service. This vessel was 200 feet long by 29 feet beam by 18 feet 6 inches deep, and fitted with a direct-acting condensing engine of 40 inches by 36 inches. The plate iron for this vessel was rolled by Pratt & Co., of the Buffalo Iron and Nail Company, and with the exception of the angle bars and bulb beams that were rolled in Philadelphia, Pa., the entire construction of the vessel was of Buffalo material and manufacture. The hull of this vessel was lengthened 40 feet in 1871, and she continued in service until October 6, 1875, when she was wrecked on Racine Reef in Lake Michigan. He subsequently built the "Philadelphia" of 1,500 tons, for the same parties. There were built of iron at this yard, up to 1870, four tugs, two side-wheel steamboats each about 250 tons, two steam yachts, and two steam revenue cutters. From 1870 to 1884 there were nine steam yachts, three tugs, one steam revenue cutter, and a propeller of 300 tons. David Bell first came to Buffalo, N. Y., in 1845, soon after which time he opened a machine shop.

The King Iron Works in 1871 commenced the construction of four iron screw steamers for the Anchor Line. They were of 1,200 tons each, and named "India," "China," "Japan," and "Alaska." They built the next year the "Cuba," "Russia," and "Java," of 1,500 tons each, and in 1873 the "Scotia," of the same tonnage, and the "Arabia," of 1,200 tons. These vessels were built by Gibson & Craig as sub-contractors.

*Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

The Union Drydock Company, of Buffalo, had long been builders of wooden propellers of the largest dimensions in the lake service, but the managers of the company, seeing the trend of the times toward iron hulls, in 1881 equipped their already extensive works with a plant for building iron-hull vessels. Their first vessel, finished in 1882, was named "H. J. Jewett," of 1,953 tons, for the Union Steamboat Company, of Buffalo, N. Y.; and in the same year they completed two tugs. In 1883 they constructed the revenue cutters "Fessenden" and "Perry." The first *steel* hull built at this yard was the "Tioga" in 1885, followed by the "Susquehanna" in 1886.

The Wyandotte yard of the Detroit Drydock Company was opened for business in 1871 by Capt. E. B. Ward, who had associated with him F. E. Kirby, an engineer of marked ability. The first vessel launched from their yard was the "E. B. Ward," a propeller of 150 x 26 x 14 feet, which, after a few seasons' service on the lakes was sold and sent to the Gulf of Mexico. In the next two years they built the "Queen of the Lakes" of 260 tons; screw tug "Sport," of 86 tons, having a steel-plated hull, for Capt. E. B. Ward; and the propeller steam yacht "Myrtle." Then the financial panic of 1874 came on, when the industries of the country were paralyzed for three or more years. The ownership of this yard was consolidated with the Detroit Drydock Company in 1877. The next year they built the "City of Detroit," composite hull of 1,094 tons, and in 1879 the "Idlewild," of 312 tons. In 1880, when the revival in shipbuilding struck the lake section of the country, they received their share of the contracts. In this year they built the "City of Cleveland," the "Transport," the propeller "Boston," of 1,829 tons, for the Western Transit Company, the largest vessel they had built to that time, also the propeller "Lehigh," of 1,704 tons, for the Erie and Western Transit Company; and the next year the "Brunswick," "Clarion," and "City of Milwaukee," all iron propellers, and in 1882 the "Michigan," and the "Wisconsin," of 1,200 tons each, having double bottoms 3 feet deep, the first of that type built at this yard. Then in 1883 the "City of Mackinac" for the Detroit and Cleveland Steam Navigation Company, the transfer steamer "Michigan Central," and Grand Trunk Railroad transfer steamer "Lansdowne." In 1884 the *steel-hull* propellers "Albany" and "Syracuse," for the Western Transit Company, of 1,900 tons each. These were the first steel hulls built on the lakes since the tug "Sport" was constructed at the same yard eleven years before. In 1885 the "City of Cleveland," of 1,900 tons, and the twin-screw steamer "Verona," both of steel.

The Chicago Shipbuilding Company, formed of interests in the Globe Iron Works and the Illinois Steel Company, was organized in December, 1889, and the following July the keels were laid of the two steel-hull propellers, the "Masaba" and the "Mariana," of 2,400 tons each, constructed for the Minnesota Steamship Company.

F. W. Wheeler & Co., who had been building for several years wooden-hull vessels for the lakes at West Bay City, Mich., in 1888 fitted up their yard for constructing iron and steel hull vessels, and on March 18, 1890, launched their first steel vessel, the sidewheel passenger steamer "City of Chicago," for Graham & Morton, of Benton Harbor.

The Cleveland Shipbuilding Company was organized by taking over the Cuyahoga Steam Furnace Company's Works and a drydock company. The former plant was built in 1836 to manufacture steam engines at Ohio City, and had a furnace at Dover. Their original plant was driven by a 12-horse-power high-pressure engine built by P. B. Andrews, of Cleveland, Ohio, who was about the largest builder of marine engines for lake vessels of that period. The Cuyahoga Company also built several marine engines. The Cleveland Shipbuilding Company equipped their works with modern tools for iron and steel shipbuilding in 1887, and the next year built the steel-hull steamer "Lackawanna," and car ferry steamer "Transfer," and in 1889 the "Scranton" as a mate to the "Lackawanna."

The American Shipbuilding Company was organized in April, 1899, by the consolidation of the Cleveland Shipbuilding Company, the Globe Iron Works Company, Shipowners' Drydock Company, Chicago Shipbuilding Company, Superior Shipbuilding Company, Detroit Shipbuilding Company, and the Milwaukee Drydock Company.

The Globe Iron Works, of Cleveland, Ohio, had been for many years constructing engines and boilers for lake steamers on a large scale, and in 1880 the owners prepared to extend their plant sufficiently to include the construction of iron hulls, and thus be able to complete a contract for an entire vessel within their own works. In 1881 they began the construction of their first iron vessel, and in the spring of 1882, the "Onoko," as she was named, was launched. As this vessel was the pioneer of an advanced type for lake navigation, a radical departure from anything then in service on those waters, a few items of detail of the vessel may be of interest. Dimensions of hull 258 feet between perpendiculars, 39 feet beam, 25 feet from spar deck to base line, with double bottom for water ballast. Tumble home, topside at plankshear 8 inches. Keel 11-16-inch iron; angle iron 3 x 3½ x ⅜ inches; floor plates, 5-16 inch; one main keelson ⅝ inch, 3 feet 9 inches high, continuous fore and aft, and fastened to keel by angle irons 4 x 4 x 7-16 inches. Three side keelsons on each side of main keelson of same height as the latter, and spaced 4½ feet apart; they support the deck of the double bottom, and are made of ⅜-inch iron. The double bottom extends from collision bulkhead to engine bulkhead, having a capacity of 700 tons of water, and is divided into six compartments by transverse bulkheads. Plating, in-and-out strakes, 9-16-inch iron from keel to lower deck, then ½-inch, and sheer strake ⅝ inch. Beams of lower deck bulb T-iron 10 inches deep, and upper deck 8 inches. There were originally two firebox boilers, each 18 feet long and 8 feet 8 inches diameter, tested for a working pressure of 100 pounds of steam. One fore-and-aft compound engine having cylinders 30 inches and 56 inches by 48 inches stroke, with cranks set at right angles, placed well aft in the vessel. This was the pioneer all-iron freight boat, and was something of an experiment on the lakes at the time, but she fully sustained the promises that were made for her of a serviceable and economical boat in operation, and a good paying vessel for the owners.

These builders constructed further but few iron vessels, a small sidewheel vessel and two tugboats, as the steel-hull era set in so soon after their establishing a shipbuilding plant that their construction of vessels has been almost entirely since of steel.

The Globe Iron Works was purchased by a syndicate of Cleveland capitalists in 1886, and the name of the corporation changed to Globe Shipbuilding Company.

WESTERN RIVERS.

There were no iron-hull vessels constructed on the western rivers after the building of the naval steamer "Alleghany" in 1847, until the iron-hull monitors were built for the U. S. navy during the rebellion. The abundance of ship timber and its low price in the western States, with the elasticity of the light wood frame of these river steamboats, that must in many cases in their navigation run over very shoal places, and often touching the bottom of the river, gave the preference to the wooden hull. The additional cost of original construction was a factor of no small moment, that prevented the development of the iron-hull steamboat on the western rivers.

During the civil war the United States government contracted for the building of eighteen iron-hull monitors in the middle western States. Of these, eight were built at St. Louis, Mo.; five at Cincinnati, Ohio; four at Pittsburg, Pa., and one at Mound City, Ill., the largest being the "Tippecanoe," "Catawba," and "Oneota," of 1,034 tons each. Of these eighteen vessels, but seven were completed prior to the close of naval operations on the western rivers. The "Winnebago" and the "Chickasaw" were in the engagement in Mobile harbor on August 5, 1864, under Admiral Farragut, and these two vessels took a prominent part, with the other ironclads, in the battle with the rebel ironclad ram "Tennessee," and did good service. In 1877 the hull of the "Winnebago" was altered to a stern-wheel freight boat and named "Charles P. Chouteau," and after being lengthened was 296 x 54 x 8 feet. In 1881 the "Chickasaw" was altered to a sidewheel transfer boat.

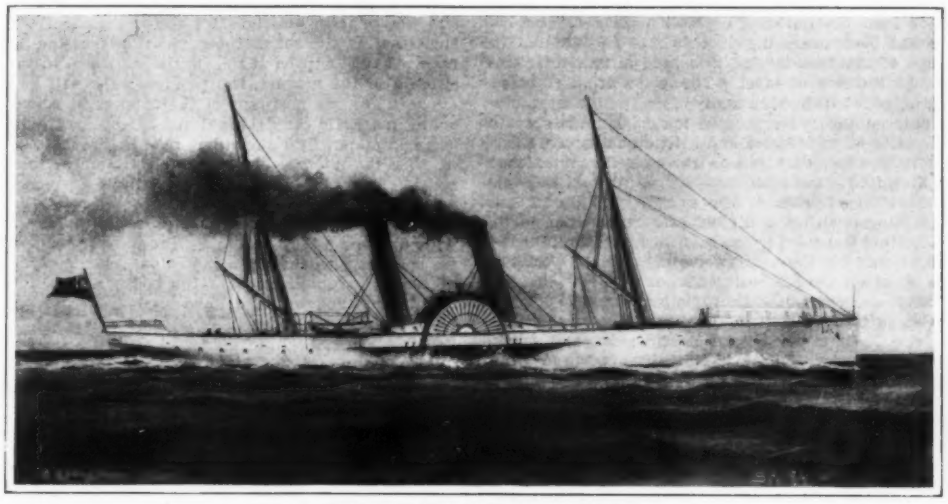
There was no further construction of iron-hull vessels on the western rivers until the Iowa Iron Works, of Dubuque, Iowa, the builders of the torpedo boat "Ericsson" in 1893 for the U. S. Navy Department, built the steamboat "Clyde" in 1869-70. This was the first iron-hull steamboat built in the West since the "Valley Forge" of 1840, and she was 135 x 19 x 4 feet, with two high-pressure engines, each cylinder 12 inches diameter and 78 inches stroke, with two flue boilers. The vessel was subsequently altered to a sternwheeler, and is still in use. In 1872 they built the "J. G. Chapman," a sternwheeler, of 125 x 30 x 6 feet, with similar machinery to that of the "Clyde." Then for several years there were no iron hulls built at this yard, but with the advent of the steel era in shipbuilding a change took place, and there has since been more activity in the construction department at these works.

The Western Iron Boat Building Company at Carondelet, Mo., was established in 1874 by Charles P. Chouteau, of St. Louis, Mo. The latter was also largely in-

terested in the Laclede Rolling Mills, of that city, that furnished a large amount of the plate iron for several of the monitors built in the western States. This shipbuilding plant was originally run under the management of Theodore Allen, an engineer from New York city, who subsequently, with A. H. Blaisdell, became the owner. This yard built many iron-hull vessels for the western rivers: In 1874 the snag boat "O. G. Wagner;" in 1875 the sternwheel tugboat "A. G. Humphries;" in 1876 tugboat "W. J. Florence;" and in 1877 tugboat "Bessie," freightboat "Charles P. Chouteau" monitor "Winnebago") and the twin-screw propeller "Indianola" as a U. S. mail boat; in 1878 four sidewheel U. S. survey steamers; in 1879 the sidewheel snagboat for the U. S. government, "H. G. Wright," whose dimensions were 187 x 62 x 8 feet. The next two years they built two snagboats, two survey boats, and two propellers. In 1881 they altered the monitor "Chickasaw" to a sidewheel transfer steamboat named "Gouldsboro," for the Texas & Pacific Railroad Company, and the vessel is still in use. The hull of this vessel was used as a lighter to transfer coal to steamships at sea, prior to the jetties being built at the mouth of the Mississippi River. During the same year they built two iron-hull towboats 175 feet long each, for the Mississippi River Improvement Commission. The company subsequently went out of business, the machinery and tools being removed to the yards of Edward Howard at Jeffersonville, Ind., where there have been some steel vessels built of later years. The Western Iron Boat Building Company introduced into some of the vessels built at their yard the longitudinal system of framing, but its increased cost prevented many owners of steamboats from adopting it in construction.

Iron shipbuilding was also carried on by M. A. Sweeney at Jeffersonville, Ind., and by the Springfield Boat and Manufacturing Company at Springfield, Ind., and the American Boat Building Company at St. Louis, Mo.

There was no further construction of iron-hull vessels on the Ohio River until 1871, when Alexander Swift & Co., of Cincinnati, Ohio, who had an iron rolling mill on the Ohio River, and had built three of the iron-hull monitors for the western rivers, constructed the sternwheeler "John T. Moore" for the Red River service. The hull was originally 191 x 42 x 7 feet, and fitted with two engines, each having cylinders 22¾ inches by 6 feet stroke. In 1881 the vessel was purchased by the Texas and Pacific Railroad Company and altered to a sidewheel transfer boat, and name changed to "Endeavor." In 1883 the hull was lengthened about 40 feet, and the vessel was continued in service to 1901. In 1873 the same builders constructed the "Alexander Swift" as a towboat for their own use. The hull was 151 x 28 x 5 feet 7 inches with two engines 21 inches by 7 feet. This vessel was subsequently sold to W. H. Brown & Sons, coal operators at Pittsburg, Pa., and in 1891 the vessel was lengthened 27 feet and name changed to "Mariner," and is still in service.



BLOCKADE RUNNER "BANSHEE."

PACIFIC COAST.

Iron shipbuilding on the Pacific Coast was inaugurated by the opening of the Union Iron Works at San Francisco, Cal., in 1884, in the construction of a steam collier for the Pacific Coast. They built but very few iron hulls, as the age of steel had well progressed before they were in active operation. There had been a few iron vessels wrecked on that coast, which had received very extensive repairs at the Risdon Iron Works in San Francisco, prior to 1884, but there were no new iron vessels constructed on that coast until the date named.

STEEL SHIPBUILDING.

BLOCKADE RUNNERS.

The first hull of a steam vessel where steel plate was used in its construction, in this country, is known to have been built in 1873, but it is not so well known that the U. S. navy had *all-steel* and *steel-plated* steam vessels in its service many years before this date. These vessels were forced contributions to its service during the civil war of 1861-65; otherwise, they were captured blockade runners. Not all these vessels were taken into the naval service, for several were purchased by parties for the merchant service at the same period. They were all built in Great Britain, mostly at Liverpool, while a few were built on the Clyde River in Scotland.

The first eighteen months of the war, the vessels that were sent out to run the blockade of the southern ports were of a very indifferent type of vessel for the risk; but as the blockading fleet became larger in numbers, and more efficient in the duty assigned them, it was found necessary to have a different class of vessel from any then engaged in breaking the law. Accordingly, vessels were designed of lighter construction and higher speed, expressly for the purpose of running the blockade. Steel plate had been used for a few coastwise and river boats before this in Great Britain, and it was now determined to make use of this then untried metal in the construction of a sea-going steamer. The first vessel that was laid down for this special service, and built of all steel, was the "Banshee," constructed by Jones, Quiggins & Co., of Liverpool, and completed in May, 1863. The vessel was 214 x 20 x 8 feet loaded draft, and fitted with two oscillating engines, feathering paddle wheels, and two boilers. The shell plating of the vessel was ⅛ inch and 3-16 inch thick. The manager of the fleet to which she belonged says: "Considering how frail the vessel was, the wonder is, not that the 'Banshee' was driven back (in a heavy storm), but that she ever got across the Atlantic at all." This vessel was the first of a fleet that soon became famous, and was the first steel vessel to cross the Atlantic Ocean. This vessel was captured November 21, 1863, purchased by the Navy Department March 12, 1864, after the captive had passed through the prize court, and fitted out as one of the blockading fleet. The service was limited, as most of the time the vessel was at the machine shops for repairs. She was sold after the civil strife was over by the Navy Department and placed in the merchant service, the name being changed to "J. L. Smallwood." The last known of her under the American flag was as transporting cattle in the Gulf of Mexico to the island of Cuba. She subsequently passed into foreign hands, and was known as the "Irene" in the Bahama Islands. That seems to be the record of the first steel steam vessel under the American flag, though of foreign build.

The Navy Department had another of the same type of vessel in its service, named originally the "Bat." This vessel was constructed by the same builders in 1864, and was 230 x 26 x 9 feet 6 inches, with a loaded draft of 6 feet 6 inches. The motive power was two oscillating engines, each having cylinders 52 inches by 4 feet stroke. This vessel was captured October 16, 1864, with a cargo mainly of machinery. The Navy Department purchased this vessel, fitted her with a light gun battery, and assigned her to the blockading fleet. She was subsequently sold, entered the merchant service, and for two or three years run in the coastwise trade under the name of "Teaser." This vessel and some other ex-blockade runners were subsequently altered to towboats for the lower Mississippi River.

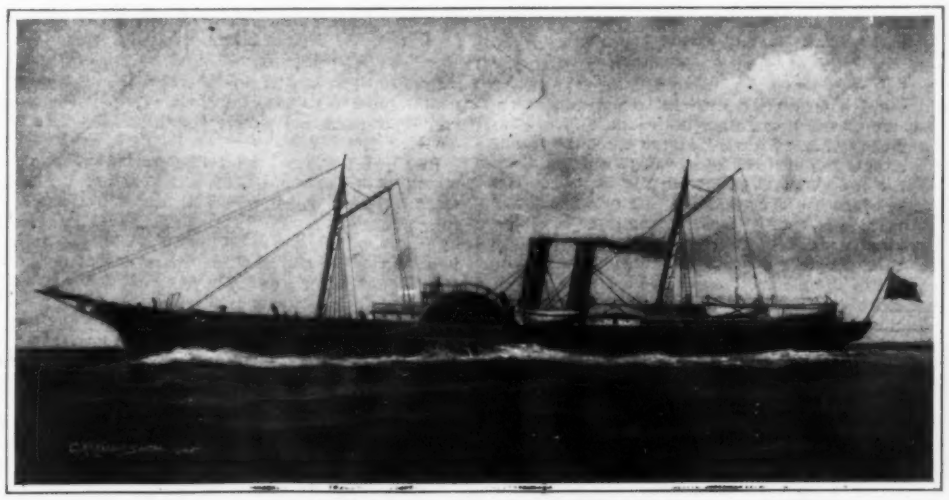
There was also the "A. D. Vance," steel plated, built on the Clyde by Caird & Co. as the "Lord Clyde" in 1862, with dimensions of 236 x 26 x — feet. After her capture the vessel was purchased by the Navy Department in September, 1864. This was a larger and more substantially built vessel than those previously named. She was taken into the blockading fleet as the "Advance," and after the war name changed to "Frolic." She was on the European station, and in the South Atlantic squadron, and was sold when the unserviceable vessels of the navy were disposed of in 1883.

The "Lillian" was another of those steel vessels built on the Clyde in 1864, and was a very fine vessel for the special service of blockade running. She was captured in the summer of 1864, and the Navy Department having purchased the vessel, fitted her with a light battery, and placed her in the blockading fleet off Wilmington, N. C. She was sold at the close of the war, put in the merchant service in the Gulf of Mexico for a few years, and at a later period she was found as the "Cespedes" in a Cuban filibustering expedition, in company with that well-known filibustering vessel of that time, the "Cuba," ex "Hornet," and ex-blockade runner "Lady Sterling." The latter was taken after her original capture in 1864 and fitted up handsomely as President Lincoln's yacht, so called at the time. She was sold by the Navy Department about 1867, and shortly after her illegal service was begun. She was in the "lime light of publicity" in 1869, through her operations in the cause of Cuban independence, and gave the U. S. government much trouble at the time to see that her owners did not transgress the neutrality laws of the country. She was not the only vessel the authorities were compelled to closely watch at the time.

There were many captured blockade runners having all-iron hulls, and taken into the naval service during the civil war, but none having steel in their construction originally, so far as the record shows, except those named. If there were others, all trace of them appears to be lost.

It is not known just how many of these steel vessels were constructed for this special service; but it cannot be an exaggeration to say there were forty at least of them built. The Liverpool builders constructed up to 1866 sixty steel-hull vessels, steam and sail. The steel plate mainly used in building these vessels was rolled from ingots made by Henry Bessemer & Co., steel manufacturers, by Marriott & Atkinson, of Sheffield. At first the frames of these vessels were of so light material that with their large engine power the hulls were strained very badly when the vessels were put to the top of their speed, as they often were on being chased by some of the blockading fleet. They have often arrived at their destination with the seams of the plating of the underbody opened so much, that it was with difficulty that the pumps kept the vessels afloat. The later vessels were mostly larger and built of heavier material, and of more comparative engine power than those constructed at first.

But few of this higher class of vessels fell into the hands of the blockading fleet. The finest of this fleet of vessels was the "Col. Lamb," the property of the Southern Confederacy. This vessel was built by Jones, Quiggins & Co., late in 1864, and was a paddle-wheel steamer of 281 x 26 x 11 feet, fitted with two oscillating engines, and the hull divided by four water-tight bulkheads. On her trial trip, in a two-hour run, she made 16¾ knots, or 19.3 miles per hour. This vessel was the greatest development of the blockade runner of that period. The machinery for the "Bat," the "Col. Lamb," and the "Owl," another one belonging to the Southern Confederacy, was constructed by Laird & Co., of Birkenhead, and had each two oscillating engines with cylinders of 52 inches diameter and 4 feet stroke, operated at a steam pressure of 30 pounds.



BLOCKADE RUNNER "A. D. VANCE."

Among the steel vessels that were captured, sold by

order of the prize courts, and purchased by private parties, were the following: The "Lucy" was placed in the coastwise trade, where she remained for three or four years. The "Tartar" ex "Wren," built by Laird & Co., was sent to the Gulf of Mexico, and ended her career as a towboat on the lower Mississippi River. The "Savannah" ex "Hope," one of the larger type of vessels belonging to the Southern Confederacy when captured, was under charter to the government, and in the merchant service for about five years. There was also the "Palmyra" ex "Deer," and the "Zenobia" ex "Stag," large sidewheel vessels, built at Newcastle, England, that were bought by Boston parties, and run from Boston to the Gulf of Mexico, and subsequently to South America, for a few years, where their record under the American flag closes. There was an all-steel twin-screw propeller of 550 tons, built in 1863 at Hull, England, that became a blockade runner, but under what name she was captured there appears no way of ascertaining at present, though she was launched and in our coastwise service as the "Pelican." There is no steam vessel of that name in the record among those captured by the blockading fleet. The owners of these vessels often resorted to a change of the vessel's name, so as to cover her identity in case of capture. In many cases, the captors have been unable to find on the vessels any papers whatever showing name or ownership, or anything to identify the vessel, they having been thrown overboard when capture became imminent.

In 1864 Laird & Co. built four paddle-wheel steamers having frames and shell plating of puddled steel for the same service, named "Lark," "Wren" (which was captured), "Isabel," and "Penguin. The first two of these were each 211 x 23 x 10 feet 9 inches, and were fitted with oscillating engines of 120 horse-power nominal. The two last-named were each 246 feet 8 inches x 30 x 13 feet, and fitted with same type of engine of 260 horse-power nominal.

The Southern Confederacy, through its Treasury Department, started an opposition line of blockade runners of their own in 1863, composed of five steel vessels similar to the "Banshee," and named "Cerus," "Venus," "Hebe," "Juno," and "Vesta," to bring in the supplies necessary for the army and navy of the Confederacy, and to run out the cotton in bales to Nassau, for shipment to England, to pay for the supplies furnished. These vessels were singularly unfortunate, or otherwise, for they all ran ashore on their first or second voyage. It was claimed at the time that they interfered with the business of those large trading companies, so called, that had so many vessels in the contraband trade at the time. This would appear to have some ground of truth, for most of the Confederate blockade runners of a later date had Confederate naval officers as commanders.

How these steel-hull vessels were constructed may be seen from the following report as to the condition of the U. S. S. "Bat," then a month or more in the U. S. navy, and but about nine months old: "I would again respectfully call your attention to her. Lying in the smooth water of the James River, she leaked 20 inches in 24 hours. By the settling of the deck amidships, the woodwork has encroached so much upon some of the working parts of the machinery as to necessitate the cutting away of a portion of it. The tubes in the boilers have begun to give out. Twenty in one, and five in the other boiler are now plugged. Those and other matters reported by the engineer in charge, have been referred to the fleet engineer. Her decks require thorough calking, some of the seams being nearly three-quarters of an inch wide, with nothing in them."

As further evidence of the frail structural work of many of these vessels, an English engineer of that period said: "There is no doubt that the blockade runner 'Lelia,' which went down off Llandudno last year (1865) with Mr. Thomas Miller, of Liverpool, on board, foundered because of some of her steel plates giving way below the water line. She was strongly framed, but, like all those boats, heavily engined, and her commander, in spite of proper precaution, pushed her ahead against a heavy sea, and thus the very power which would have carried a rigid iron vessel safely through the waves, became her destruction. The powerful engines would, as it were, almost force the framework through the delicate steel shell, causing it to buckle and crumple, and give from the rivets, against the mighty pressure of the waves. Many shipbuilders say, at the present time, that the difficulty of obtaining one hundred or even fifty tons of steel of uniform quality throughout is a great hindrance in many instances to its adoption."

We cannot obtain a better view of the conditions surrounding the use of steel plate in shipbuliding in Great Britain at this early date, than from the opinion given of its use by J. Scott Russell, the noted English naval architect, in 1866: "Most of us have already tried the building of steel ships, and those who have not done so, have been sorely pressed to do so by those who think well of that material. I, myself, am one of these who think well of it, but who doubt whether we yet possess data to enable us to proceed with certainty to build large floating structures, wholly or chiefly composed of steel. I was told by those using steel plates which had a tensile strength of 40 tons to the inch, I should be able to build a ship of half the weight of a ship built of iron plate having a tensile force of only 20 tons to the square inch, and so effect a saving in weight of the greatest importance. I have reason to think that several vessels have been built of steel in the belief that this statement was true, and that a vessel of half the thickness in steel would be as strong as another of double the thickness in iron. But these vessels have, I think, disappointed their builders and owners in several ways not anticipated, and such experiments have discouraged the use of steel unreasonably, for I am prepared to believe that there are cases in which ships of steel would be very valuable, provided we had sound data on which to construct them with certainty. At present the difficulties of steel shipbuilding are more formidable than those of steel engineering."

After 1866 the building of steel vessels fell off, as there had been many disappointments encountered in the use of the vessels, and this bred a want of confidence in the use of steel. The price of steel being much higher than iron, in many cases the lowest quotation secured the order for the material, and in some cases plates of an inferior and brittle quality were furnished. Besides, they passed through the experience of finding that a too high tensile strength had been acquired at an expense of the ductility of the metal. These things, with the higher price than iron plate, were against the further use of steel in shipbuilding at the time, and for the next twelve years there were not more than ten vessels built of steel in Great Britain, and they were of small dimensions. The era of steel here began in 1878, and in that year there were eight steel vessels built of Siemens-Martin steel, and seventeen constructed of Bessemer steel, twenty-five in all.

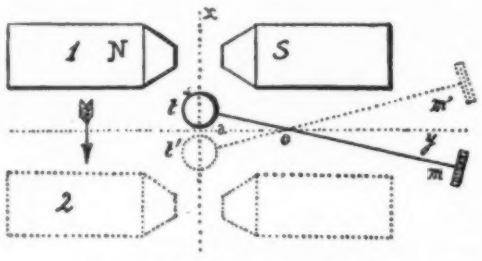
The first steel-hull steam vessel built in any country, so far as at present known, was that constructed by John Laird, of Birkenhead, England, and completed in February, 1858, for Dr. Livingstone's second expedition to Africa, and named "Ma-Robert." The vessel was a paddle-wheel launch of 75 x 8 x 3 feet deep, with a non-condensing engine. The hull of the vessel, as well as the boiler, was built wholly of Howell's homogeneous metal, or puddled steel, that was something new in the steel plate line at the time in England. These plates were 1-16 inch thick for the hull, and were then thought to be stronger than ¼-inch iron plate for the same purpose; and the maker of this steel plate considered it could be depended upon for a tensile strength of 50 tons. This plate sold at the time for $250 per ton. The vessel was sent out to Africa on board of a vessel in three sections. From all accounts, the wearing qualities of this steel in the hull of the vessel was not of the best, though the vessel, no doubt, had a very hard service to perform on the shoal rivers of Africa. It scaled off on both sides of the sheets in large pieces, so that in a few months after the vessel was in service, the steel plating was in many places not more than 1-32 inch in thickness.

(To be continued.)

MEASUREMENT OF THE SPECIFIC MAGNETIZATION OF DIAMAGNETIC OR SLIGHTLY MAGNETIC BODIES.*

By EMILE GUARINI.

M. P. CURIE, who is so well known from his researches in radium, has, in conjunction with M. C. Cheneveau, recently designed a very interesting apparatus for the measurement of the coefficient of specific



MEASUREMENT OF THE SPECIFIC MAGNETIZATION OF DIAMAGNETIC BODIES.

magnetization of diamagnetic and slightly magnetic bodies, and the Société Centrale des Produits Chimiques, of Paris, has undertaken the construction of the device.

In this apparatus the force exerted upon a body placed in a magnetic field which is not uniform is utilized. The magnetic field is created by quite a narrow magnet of annular form. The force is measured by a torsion balance. The horizontal rod of the latter is supported at o by a wire. From one of its extremities is suspended vertically a glass tube, t, which is closed at the bottom and in which is placed the body to be studied, either in a liquid state or in the form of a powder. To the other end of the rod is fixed a micrometer, m. The displacements of the micrometer are observed by means of a microscope provided with a hair-cross. The oscillatory motions of the balance are reduced by pallets operatively connected with the rod and movable in a vessel filled with oil of vaseline.

The cut shows in horizontal section the relative positions of the tube, t, containing the body, and of the magnet, which occupies position 1, for example. If the body is para-magnetic, an attraction will occur, and the force will be exerted upon the body in the direction $a\,x$. It is possible to displace the magnet parallel with itself by means of a micrometric screw which acts upon a properly guided carriage upon which it is mounted. The displacement of the magnet occurs in the direction indicated by the arrow. To each position of the magnet there corresponds a different force exerted upon the tube, and, consequently, a different situation of the micrometer. For a certain position of the magnet, the tube, t, is symmetrically placed between its poles, and the force is null. Upon continuing to displace the magnet beyond this position, the force exerted upon the body changes direction, and the relative positions of the magnet and tube are such as 2 and t'.

If the body is diamagnetic, a repulsion will occur, and the relative positions for the equilibrium will be such that if the magnet occupies the position 1, the repulsed tube will be at t'. On the contrary, in the position 2 of the magnet, the repulsed tube will be at t.

There are two positions of the magnet in which the acting magnetic forces, equal and of contrary polarity, are maximum. The deviations read in the micrometer, m, with the microscope are also maximum at this moment. Their difference, Δ, is measured by operating with a mass, m, of the body. Suppose, then, that Δ be the resultant of an analogous measurement made with a mass, m', of water; Δ the measurement when we operate with the glass tube alone; k the coefficient of specific magnetization of the body; and k' that of the water; then we shall have

$$\frac{k}{k'}=\frac{\Delta-\Delta''}{\Delta'-\Delta''}\frac{m'}{m} \qquad (1)$$

Δ Δ'' Δ' must be taken as positive or negative according as the tube is attracted or repulsed. For the water, Δ'' will always be negative. In order to have the absolute value of k, it is possible to admit, for the water, that $k' = -0.79 \times 10^{-6}$ at the ordinary temperature.

The formula (1) is only approximate. It does not take into account the magnetism of the air. The exact corrected formula of this effect gives for the relation sought:

$$\frac{k}{k'}=r\left[1+0.039\left(\frac{1}{rD}+1\right)\right]$$

in cases in which the comparison is made with water. In this formula, r is the approximate value of kk' given by formula (1) and D is the density of the body.

A numerical example will show the thing more clearly. Let us suppose, in the first place, the case of a magnetic body, say anhydrous sulphate of manganese, for which

$\Delta = +149.2$ divisions.
$\Delta' = -2.1$ divisions.
$\Delta'' = -1.0$ divisions.
$m = 0.124$ gr.
$m' = 0.123$ gr.
$D = 2.95$

$$\text{Then } r=\frac{k}{k'}=\frac{\Delta-\Delta''}{\Delta'-\Delta''}\times\frac{m'}{m}=\frac{150.2}{-1.1}\times\frac{0.123}{0.124}=-135.44$$

Whence $k = -140.72\ (-0.79)10^{-6} = 111.2 \times 10^{-6}$.

Let us now suppose a diamagnetic body, say anhydrous sulphate of potash :

$\Delta = -9.1$ divisions.
$\Delta' = -9.7$ divisions.
$\Delta'' = -1.1$ divisions.
$m = 1.653$ gr.
$m' = 0.934$ gr.
$D = 2.65$.

$$\text{whence } r=\frac{k}{k'}=\frac{-8.0}{-8.6}\times\frac{0.934}{1.653}=0.525.$$

$$\text{and } \frac{k}{k'} \text{ corrected} = 0.525\left[1-0.039\left(\frac{1}{0.525\times 2.65}\right)-1\right]=0.530$$

and $k = 0.530\ (-0.79) \times 10^{-6} = -0.42 \times 10^{-6}$.

In the case of a solution or of a mixture of two bodies, if x is the percentage proportion in weight of one of the bodies, we may deduce the coefficient k, of such body from the coefficient, k, of the solution or of the mixture by the general formula $100\ k = (k,\ x + (100 - x)k'$, k representing the coefficient of the solvent or of the second mixed body.

As for the *modus operandi*, that is very simple. The rod resting upon two hooks and the wire being slightly slackened, we unscrew the plug placed upon the cover of the apparatus and place the glass tube in the rings arranged at the end of the rod. We then place the magnet in such a manner that the register mark upon the carriage shall coincide with the zero of the graduation indicated upon one of the slides that serve to guide the carriage. Then we slightly raise the torsion wire in such a way as to permit of the oscillations of the balance. The deadener should then be entirely immersed in the vaseline. For this purpose, if need be, we give the wire a slight twist in order to bring the micrometer under the microscope. We then place the balance in equilibrium so that the glass tube shall be placed symmetrically between the pole pieces of the magnet. For doing this two travelers are employed. After having regulated the micrometer by means of a mirror added to the apparatus, we focus the microscope, and then move the magnet gradually backward and forward by means of a screw, and cause it to perform its entire travel by revolving the screw always in the same direction, the while observing in the microscope the two positions of the micrometer for which the deviations are maximum. The series of operations just mentioned are performed in succession with the tube containing water and with the tube containing the body to be studied; and we thus obtain Δ'', Δ', and Δ. A register mark upon the tube indicates the height to which it is proper to fill it with the body and the water.

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

[Concluded from SUPPLEMENT No. 1557, page 24965.]

OLD AGE.*

By ELIE METCHNIKOFF, Subdirector of the Pasteur Institute.

IN the case which we have just cited there occurs an acute poisoning, occasioned by the toxic products of microbes and of mushrooms introduced into the intestines. Now, there is no doubt but that there occur besides these examples others in which the poisoning is less violent and less rapid and in which the microbes of the intestinal contents secrete their products for a long time, thus setting up a chronic poisoning. It is exactly among these products that we should seek for the cause of the weakening of our noble elements and the stimulation of the destructive activity of the macrophages. It is true that certain poisons once absorbed by the organism initiate the production of counter poisons. Thus, Ehrlich, after having caused his mice to swallow quantities of vegetable toxines, ricine and abrine, proved that the blood of these animals became the best antidote against these poisons. The human organism after absorbing for years the microbic products elaborated in the intestines might indeed thus acquire an immunity with regard to them. This supposition is very probable, but it does not at all apply to a whole series of microbic poisons, such as the phenolic substances, the ammoniacal salts, and others, for their absorption occasions no production of counter poisons.

According to the hypothesis we are advancing, the principal phenomena of old age depend upon the indirect action of microbes that become collected in our digestive tube. And, since the wearing away of the substance of the bones in tuberculosis and leprosy is effected by osteoclasts excited by the poisons derived from the bacilli characteristic of those two maladies, so the same wearing away of the bones may come from a stimulation of the same osteoclasts by the poisons of intestinal microbes. If this is the case, our organism contains within itself the cause of its own destruction, in the same way that grapes carry upon their surface the germs of the ferments that set up alcoholic fermentation by destroying the sugar the fruits contain.

This hypothesis rests upon a great number of well-established facts, but it lacks direct proof, which can only be furnished by investigations carried on for long years. In this imperfect state it becomes necessary to bring together as many arguments as possible in order to justify our supposition.

If it is really intestinal microbes that are the cause of our senile atrophy, we must believe that the more the flora of the intestines is reduced the fewer manifestations of old age there will be.

If we compare an old mammal with an old bird we are at once struck with the great difference in their external appearance. An old horse or an old dog can easily be recognized by its ugliness, its lazy movements, its worn teeth, its lusterless hair turned white on certain portions of the body. A dog of 12 to 15 years shows very markedly all these signs of senile decrepitude. Birds keep their age much better and longer than mammals do. An aged duck, more than 20 years old, is alert in its movements and does not show externally any sign of its advanced age. Parrots and parroquets also remain for long years in a very youthful state. A little parroquet from 15 to 19 years old, which I observed very closely for several years, manifested no signs whatever of old age. It was very lively and curious, interesting itself in all sorts of things about it, and its plumage was brilliant and richly colored. We have possessed for some years past a parroquet that, according to reliable information, must be from 70 to 75 years old. It is impossible to recognize its advanced age, so normal is its appearance and so easy are its movements.

The few examples just cited confirm the general rule that birds have a much greater longevity than the large majority of mammals. Now, birds are distinguished by having an intestinal flora very much poorer in microbes than that of mammals. Possessing no large intestine, birds lack that great reservoir for alimentary refuse which, in mammals, breeds an enormous quantity of all sorts of microbes. A very simple method of assuring ourselves of this consists in a microscopic examination directed toward ascertaining the comparative quantity of microbes contained in different parts of the digestive tube of a small mammal, a white mouse for example. We find quite a large number in the stomach; very few in the upper portions of the small intestine. The lower part of the small intestine contains many microbes, but it is in the cæcum and the large intestine that are found quantities truly enormous. The examination of the digestive organs of a small bird, a canary for example, having the same weight as the mouse above mentioned, gives quite a different result. In canaries microbes are found, but in very small numbers. The stomach and the small intestine contain throughout their course only a few isolated specimens. The inferior portion of the intestinal tract contains a few more microbes, but their number is very far from being equal to that found in the mouse. The cæcum, that large reservoir for intestinal microbes in the mouse, is represented in the canary merely by two rudimentary *culs de sac* destitute of microbes. It is not astonishing that, under these conditions, the toxic effects derived from intestinal sources should be much less in the canary (and in birds in general) than in the mouse and most other animals. So we see that while the mouse is already old after a few years, and lives hardly five years at most, the canary is vigorous for a much longer period and may attain the age of 15 or even 20 years.

When we see that cold-blooded vertebrates, such as turtles and crocodiles, attain a very advanced age without showing any extensive signs of senility, we are tempted to ascribe this fact to the rather inactive life of those animals. As they do not need to maintain a high bodily temperature, they take but little food and are not forced to expend much energy in procuring it. Birds have none of these advantages. They lead a very active and agitated life; in order to preserve their normal condition they must maintain a higher bodily temperature than is necessary for mammals, yet they attain a greater and more active old age than do mammals, even including man.

Notwithstanding the great difference between the life of birds on the one hand and that of turtles and crocodiles on the other, these animals have this point in common, that in them the large intestine is very slightly developed, if not absent, and their intestinal flora is extremely scanty.

In spite of the imperfect state of our knowledge at the present time, the mass of facts we have cited may well justify us in maintaining the hypothesis that the intestinal microbes play the part of one of the preponderant causes of that chronic malady, our old age.

Since science has already found very efficacious means both for protecting the organism against infectious maladies and for curing such maladies when they are not too far advanced, why should not one seek for something to render old age less painful, it also being a state which should be considered as having a microbic origin?

If, as seems more and more probable, the source of our early decay is found in our intestinal flora, we ought to seek some means either for eliminating it more or less completely or for modifying it profoundly. The idea of suppressing the large intestine, that useless part of our digestive tube that we have inherited from our animal progenitors and that serves as the principal reservoir for noxious microbes, can not be considered seriously. It is evident that we can not count upon the extirpation or even upon the surgical exclusion of the large intestine. In the cases in which this operation becomes unavoidable we find that the organism tends to form a second large intestine. We have under observation at the present time a young woman in whom the suppression of the greater part of this organ, made nearly a year ago, has by no means suppressed the disadvantages due to intestinal microbes. It even seems that there is produced at the expense of the remaining portion of the large intestine a pocket which collects the alimentary waste and nourishes a multitude of microbes.

In the present state of our knowledge we are inclined rather to consider the question of modifying our intestinal flora. There is now present in it many injurious microbes. It is only necessary to have some lesion in the intestinal wall that allows these to escape into the peritoneum to set up an infectious disease of the gravest character.

The microbes capable of inducing putrefaction are among the most dangerous. Now, these microbes have bitter enemies in other microbes, especially in those that set up the fermentation of sugars and produce lactic acid. Are there no means of acclimatizing such microbes within our digestive tube in order to combat with their aid intestinal putrefaction?

Bacteriological researches have shown that many microbes, even when taken in very large quantities, perish in the intestines of man and of animals. Thus, for example, the vibrio of cholera, that dread agent of Asiatic cholera, has many times been swallowed with impunity by various persons. Its destruction was so complete that it was impossible to find it again in the alimentary waste. Schütz introduced directly into the small intestine of dogs a quantity of vibrios which he saw soon after had disappeared. The same phenomena were observed in chickens, the microbes being destroyed in their digestive tubes.

In every attempt at a modification of the intestinal flora it is, then, necessary to find out whether a given microbe is really capable of living in the intestines. For certain lactic microbes this fact has been established by experiment. In curdled milk prepared by a ferment of Bulgarian origin, placed at our disposal by Prof. Massol, at Geneva, there is found a large bacillus remarkable for its ability to produce a great amount of lactic acid. The bacillus, when swallowed by man, does not suffer the fate of the vibrios which we have mentioned. It is not destroyed in the intestines, but passes through alive. Its presence has been demonstrated by Dr. Cohendy even many days after its introduction by the mouth. Here, then, is a microbe not normally present in our intestinal flora which may be implanted there artificially, either with curdled milk or under the form of a pure culture; endowed with great power of producing fermentation, it will be capable of effectively combating intestinal putrefactions.

It is interesting to note that this microbe is found in the sour milk consumed in large quantities by the Bulgarians in a region famous for the longevity of its inhabitants.

We have, then, reason to suppose that the introduction of this Bulgarian clotted milk into our diet may counteract, or at least diminish, the injurious effect of the intestinal flora. This would be the first example of artificial modification of that flora.

To sow useful microbes within our digestive tube is not sufficient. It is also necessary to prevent the introduction of injurious ones. With this end in view we should avoid, as much as possible, uncooked foods that serve as vehicles for all sorts of microbes. In spite of the washing of vegetables and fruits, such as salads, radishes, strawberries, cherries, and others, they are yet contaminated with dust, soil, manure, and fecal matters. Now, these often contain injurious microbes and eggs of animal parasites. Dr. Bienstock found in the earth of his strawberry beds tetanic spores, which he found would be destroyed in his own digestive tube when a little of that earth was swallowed. But we must not count too much on the antimicrobic power of our intestines, and it is much more prudent not to use these vegetables and fruits until they are cooked—that is to say, until after the destruction of all or a large part of the microbes that they contain. This measure, together with the use of water that has been boiled, will prevent, once for all, the penetration into our body of wild microbes whose injurious effects can not be denied.

Thanks to the means we have just outlined, as well as to others which we may add thereto later on, we may in the future transform our intestinal flora, now so varied and uncultivated, into a flora of much fewer species, exempt from injurious microbes but containing useful ones—in a word, into a cultivated flora.

But independently of this prospect, it is possible to avoid the disadvantages of our present intestinal flora by specific serums, prepared with a view to neutralizing the injurious action of certain microbic poisons and of destroying the microbes themselves.

As, according to our hypothesis, these microbes act upon our organism by weakening our noble elements and stimulating their adversaries, the macrophages, it will be rational to seek the means for reinforcing the former. The weakening of the latter can not be considered for the moment, as the macrophages are of great use to us in the struggle against several infectious diseases, and notably against the most terrible of all, tuberculosis.

The idea of reinforcing our noble elements is based upon the study of certain poisons called cytotoxines. Not being able to enter into the details of this question we will content ourselves with remarking that, while strong doses of these poisons destroy our cells, minute doses, on the contrary, reinforce them. We should, then, attempt to assist our noble elements in their struggle against the macrophages by the aid of cytotoxines. This problem is complex and delicate, and requires numerous preliminary researches of long duration. These were begun a year ago. At this time the question is not sufficiently mature for any kind of discussion.

The theory of old age and the hypotheses which are connected with it may be summarized in a few words; the senile degeneration of our organism is entirely similar to the lesions induced by certain maladies of a microbic origin. Old age, then, is an infectious chronic disease which is manifested by a degeneration, or an enfeebling of the noble elements, and by the excessive activity of the macrophages. These modifications cause a disturbance of the equilibrium of the cells composing our body and set up a struggle within our organism which ends in a precocious aging and in premature death, contrary to nature.

It is very probable that during the time we are growing old the intestinal microbes that have set up within our body permanent factories for different poisons play a very important part. It is, then, entirely possible to struggle against premature senility by modifying our intestinal flora and by reinforcing our noble elements, so sensitive to microbic poisons.

But, you may say, all this is theoretical. It may be scientific, but it has not been proven. You may ask me to speak to you of our present established knowledge concerning old age, of what modern medicine proposes to do in the way of remedying this unenviable condition. This question has for a long time been under consideration, and I will now give you the last utterance of empiric wisdom. A much-esteemed physician of London, Dr. Weber, who is himself very old, has quite recently summarized the means that he used to make his own age supportable and to ameliorate that of his numerous clients.

These are the rules that he drew up for this purpose: "All the organs must be preserved in a state of vigor. Morbid tendencies, whether hereditary or acquired during life, must be recognized and combated. Moderation must be used in the consumption of food and drink as well as in the pursuit of other corporeal pleasures. The air within and about the dwelling must be pure. Corporeal exercise must be taken daily in all conditions of weather. In many cases it is also necessary to take respiratory exercises as well as to walk and climb. One must retire early and rise early. Sleep should be limited to six or seven hours. Every day a bath should be taken or the body be well rubbed. The water employed for this may be cold or warm according to individual temperament. Sometimes warm and cold water may be alternately employed. Regular work and intellectual occupation are indispensable. The mental attitude should be that of enjoyment of living, tranquillity of mind, and a hopeful conception of life. On the other hand, the passions and nervous disturbances of sorrow should be combated. Finally, one should have a firm determination that will compel the preservation of health, the avoidance of alcoholic liquors and other stimulants as well as narcotics and analgesic substances."

These counsels are certainly very useful to follow, but very frequently they are insufficient for the attainment of a normal old age. Many very sober persons, not addicted to alcoholism nor any other excess, contract chronic maladies of the kidneys, of the blood vessels, of the digestive organs, and of the nervous

* A lecture given in the Salle des Agriculteurs, rue d'Athènes, July 8, 1904. Translated from the Revue Scientifique and published in Smithsonian Institution's Annual Report.

system which result in premature and most painful old age.

Empirical rules, even when dictated by the widest experience, can not, then, suffice to solve the problem, and we must seek the aid of science in order to obtain an effective result. The scientific study of old age is therefore indispensable. In order to make this study possible, we must, first of all, have material upon which to work; that is to say, old people, and, indeed, many old people. The opinion that old people are merely a burden upon society, which ought to support them simply because of our moral laws, is certainly erroneous.

Not only do the young, but many older persons share the opinion that old people incapable of work are no longer good for anything. Some ten years ago a celebrated German physiologist, who had reached a great age, told me how he felt because of his uselessness to society, and added: "What can one do? I can not decide to kill myself." Well, now that science has taken up seriously the study of the problem of old age, old people have become very useful subjects, especially so for the young, who may be able to profit by the results of these studies. If we should make way with the aged, as certain savage tribes still do, old age could never be modified nor ameliorated. If we should make way with the sick, as was formerly done, and as is still done among certain tribes, we should never discover any means for curing diseases. If we had killed diphtheritics under the pretext that the greater part of them were going to die and that they were a source of danger to their healthy neighbors, we should never have discovered the serum which now cures them.

Old people, even in their condition of decrepitude, may be very useful, on condition that scientists can be found who will undertake the task of carefully studying them. There is also a certain consolation in the thought that when we ourselves have become incapable of studying old age we may serve as subjects of study to other observers. In any case, it is to be hoped that in the future, which is, without doubt, somewhat distant as yet, old age may cease to be one of the greatest misfortunes of humanity, and that this chronic disease may yield to the ever-increasing progress of exact science.

MUFF OF MINK SKIN, SHOWING METHOD OF SEWING AND PIECING.

MINK FURS.*

By CHARLES H. STEVENSON.

THE pelage of the mink consists of dense soft fur, of excellent quality and nearly uniform on all parts of the body, overtopped by stiff, lustrous hairs about three-fourths inch long. The color shows marked variations, ranging from a light dull-yellowish brown to a dark brownish black, but is ordinarily of a rich dark brown or chestnut brown glossed with black. It is usually slightly darker on the upper parts than below, the back and tail being the darkest, and the gloss is also most marked in the fur of the upper parts. The choicest are nearly black, approximating the desirable hues of sable, these being generally from New England, the wooded districts of Nova Scotia, and the Province of Ontario. The lighter colored are of less value, and are usually dyed or blended to the desired dark shade. Albinos, as well as mottled and drab-colored pelts, are occasionally secured. Sometimes skins with white hairs sprinkled in the brown fur are obtained. Often there is a white spot on the throat similar to that of the marten, and a white spot or line of varying length sometimes occurs underneath. At times the long, bushy, and somewhat tapering tail is tipped with white. Minks from southern localities generally have fuller and thicker tails than those from farther north.

The fur is generally dark bluish-brown and sometimes dark blue in case of very dark pelts. It is dense, glossy, short, and exceedingly durable, making it one of the most economical furs in use. The skin is very thin, the thinnest of all the aquatic fur-bearers, yet it is very tough. The mink pelts from cold localities are the choicest and most brilliant; those from southern regions are coarser, harsher and with less difference between the fur and the overhair. They are marketable only when taken late in autumn, in winter, or early in spring.

When the fur of the mink was very fashionable and correspondingly high in price thirty years ago, several attempts were made to raise these animals in confinement. But it was found difficult to rear them when large numbers were kept together, the breeding being reduced and the females quarreling and fighting, and frequently killing the young. Practically all these experiments ended in failure.

MARKETS FOR MINK SKINS.

Few furs surpass that of the mink in richness of coloring, quality, and durability; yet, owing to the capriciousness of fashion, it has frequently sold at a comparatively low price. It furnishes a striking example of the vagaries of fashion in the fur trade. Formerly it was used almost solely for imitating marten. About 1860 the fashionable world took a fancy to it for cuffs, collars, trimmings, and even for garments of various sorts, resulting in increasing the market price of the pelts from about 50 cents each to $8, $10, or even $20 for very choice skins. A mink muff of good quality sold for $75 or $100, and a full-depth mink wrap sold at times as high as $1,500. Indeed, during the sixties, it was the leading fashionable fur of this country. Then its popularity gave way to fashion's demand for change of color and shorter pelage, and the price of prime skins decreased from $15 each in 1864 to $8.50 in 1866, to $3 in 1878, and to $1.25 in 1883. For many years the mink was out of favor and it almost disappeared from the market. But among those who could be independent of fashion, this warm, durable fur maintained its former popularity. It is now somewhat more in demand, but is moderately cheap compared with prices prevalent thirty-five years ago, rarely selling for more than $3 each wholesale, except for very choice skins. In consequence of its many good qualities, it merits much greater popularity than it enjoys.

About 400,000 mink skins are sold in London each year. This represents about 55 per cent of the total product of mink, the other skins being disposed of at private sale to furriers in Europe and America. About 80 per cent of the total product is obtained from within the limits of the United States, the remainder coming principally from Canada.

DRESSING MINK SKINS.

Mink skins as received at the dresser's are usually cased, the fur being turned inside and only the greasy skin appearing, and they usually remain cased during the entire operation of dressing. As may be required, the fur and the leather sides are successively turned outward, and this tedious process forms one of the principal items in dressing this fur. The first operation is to place each pelt on a beam and scrape or beam off all the grease and surplus flesh adhering to the membrane. They are next moistened on that side with salt water. After remaining thus overnight they are placed in a tramping machine, 2,000 pelts at a time, and revolved for four to six hours, until they are thoroughly softened. In the best establishments, the same result is accomplished in the tramping tubs. They are next turned fur side out and cleaned in a revolving drum containing sawdust and a few handfuls of plaster of Paris or fuller's earth. This is continued until the grease is entirely removed, when they are revolved in the beating drum and the sawdust, etc., removed.

On removal therefrom the skins are turned leather side out, moistened with salt water over night, then fleshed, as described heretofore. After fleshing, they are stretched as wide as possible with special iron stretchers, hung up and dried. The following day they are placed in the foot tubs—100 skins and 1 peck of sawdust to each tub—where they are treaded by barefooted workmen for about three hours. On removal they are stretched lengthways and beaten with rattans or in a beating drum. Then they are turned fur side out, placed in the cleaning drum with fine hardwood sawdust and revolved until thoroughly clean, which may require five or six hours. They are again placed in the beating drum to remove all the sawdust. On removal therefrom the fur is combed straight and they are turned leather side out and cleaned and polished with a fleshing knife, or, according to more recent practice, on an emery wheel.

Mink fur is manufactured into muffs, wraps, gloves, caps, and boas, either in natural state or dyed. Many skins are also used for coat linings. The tails are usually made into capes. Mink pelts are never plucked unless the overhair is exceptionally poor. This fur is very durable, lasting with moderate care a generation or more. The writer recently examined a mink muff "almost as good as new," which had been in use for more than fifty years. Mink fur is very frequently sold under the name "American sable."

* From U. S. Fish Commission Report for 1902.

THE MILKY WAY AND THE CLOUDS OF MAGELLAN.

MR. A. R. HINKS, chief assistant, Cambridge Observatory, delivered a lecture in Bloemfontein on "The Milky Way and the Clouds of Magellan," in the course of which he said:

INVERSE DISTRIBUTION OF STARS AND NEBULÆ.

From time to time great stress has been laid upon the striking facts of the inverse distribution of stars and nebulæ in the northern hemisphere. Many years ago, when fifth-type stars were unknown, and before the nebulæ had been divided into gaseous and spirals, Herbert Spencer made an excursion into astronomy and pointed out what was the logical conclusion to be drawn from the fact that stars and star clusters have a distribution inverse to that of the nebulæ in general. The fact of a definite separation, he argued, is as conclusive as would be a definite congregation, that stars and nebulæ alike form part of one definite scheme of creation; that they are not to be considered apart. And this argument has found general acceptation. The evidence which has been produced by the photographic plate has seemed to add weight, in a quite remarkable way, to the original proposition. On the one hand, we have the Milky Way, crowded with stars and clusters and gaseous nebulæ; on the other, the regions about the poles of the Milky Way, barren in stars but rich in spiral nebulæ. It has seemed inevitable that a theory of the universe which shall stand must show good reason for the clustering of stars and star clusters, gaseous nebulæ, and fifth-type stars toward one plane, and of the driving away from it of the spiral nebulæ. In the northern hemisphere the stars are crowded toward the Milky Way; the stars cluster likewise; also the gaseous nebulæ and the fifth-type stars; the spiral nebulæ, on the other hand, avoid it. These are the points for which we seek an explanation. Let us try to find it in the south. In the southern hemisphere the stars and star clusters, the gaseous nebulæ, and fifth-type stars congregate in the Milky Way and in the greater cloud of Magellan. The nebulæ are found avoiding the Milky Way, as in the north; but they also crowd into the greater Magellanic cloud to meet those Milky Way constituents with which they are associated nowhere else. A theory which shall explain the general rule of the sky must explain this striking exception also. First thoughts suggest that this must add greatly to the difficulty. Second thoughts suggest that in the exception may be found the key to the proof of the rule. There must be an explanation of these facts. One is almost tempted to say that nothing but a magnificently simple explanation is consistent with the majestic nature of the problem. But the simple explanation is still to seek.

A "CLOUD-VIEW" OF THE UNIVERSE.

I have tried to summarize the opinion which has been gradually taking shape round each new point as it arose—the view that the universe is a structure whose parts are mutually dependent; that the nebulæ avoid the star clouds because they are opposite parts of one organic whole; that definite avoidance is as clear a proof of interdependence as definite congregation. This, says Herbert Spencer, is a logical necessity, and I think the argument, as an argument, is clear. But the whole structure depends upon the strength of the evidence that all these bodies of which we have spoken are parts of one whole. Deny it successfully, and the whole fabric of argument falls to pieces. Perhaps we may find that we have been imagining in the sky a system which is not there, and seeking elaborately in the clouds of Magellan for the key to a riddle which is not there, because the riddle itself is non-existent. It would be interesting, at any rate, to try whether we can plausibly deny that there is such a thing as one systematic arrangement into which the whole universe fits; and I propose to try the experiment. I am sure you must have noticed that there were two rather thin places in the argument which I put before you just now. We said that the stars in general showed a tendency to congregate on the plane of the Milky Way; but we did not examine how far this clustering accounted for or contributed to the visual appearance of the Galaxy. And, again, we saw that the nebulæ in general avoid the Milky Way, but we did not inquire very closely whether the nebulæ got as far away as they could, which would be strong proof of a real relation, or whether they were simply not in the same regions, which might be purely accidental. Let us take the former question first, and examine with some attention a particular region of the Milky Way in the constellation Cygnus. The stars which have been catalogued, though they increase in number toward the Milky Way, do not reproduce its features. It is not they that make the Milky Way as we see it. The statistical fact that these stars increase in number toward the Milky Way is misleading if we draw from it the

conclusion which has been drawn, that they form the structure which we see. But look now at the photographs which show stars several magnitudes fainter than the catalogues. The star cloud and the rift correspond precisely with the drawing, and we may trace even the more pronounced details. We have not time to carry this comparison right along the Milky Way, as it would be very interesting to do; but I must show you how closely this experience is repeated in the smaller cloud of Magellan. We are all familiar with its appearance. If one searches for it in the catalogues of the "Cape Photographie Durchmusterung" there is no trace of it. Stars down to the 9½ magnitude are actually fewer than the average in that part of the sky, and a chart of that region would show a vacuity where the Bruce telescope at Arequipa shows not less than 300,000 stars, one of the finest examples of a star cloud in the sky. The Milky Way, then, is made essentially of clouds of very faint stars, and the brighter stars, all the stars in our catalogues, have as a whole no detailed connection with it. How is it, then, that these brighter stars are condensed, as they undoubtedly are, toward the plane of the Milky Way? I think that we may get an idea by looking again at these maps of star density in the two hemispheres. Are the stars condensed upon the plane of the Milky Way? Yes; but that is only half the truth. They are condensed in large clouds upon the Milky Way, not distributed with equal density along it. There is one large cloud over the region of Cygnus in the northern hemisphere, another broader and not so rich over Orion extending into the southern, and several more condensed and wider along by Argo and the Cross. Why should we not suppose that the stars are arranged in tumbled clouds more or less in one plane? The further, fainter and more condensed, because of their distance from us, would make the Milky Way proper; the nearer, apparently larger and more open, would make the mass of stars which we catalogue richer in the plane of the Milky Way than out of it, because the clouds are most in that plane; then the cloud of which our sun is a member would supply those nearer stars which the researches of Kapteyn and others have shown are distributed nearly uniformly around us.

THE SPIRAL NEBULÆ.

I am far from saying that the evidence is conclusively or even very strongly for this view; but it does seem to me that the idea, as a working hypothesis, has some attractions. But before we consider what possibility there is of proving its truth or error, let us see whether we can apply it to the spiral nebulæ also. I think we can. In the northern sky there is a cloud of nebulæ up about the regions of the pole of the Milky Way, but it is not by any means centrally over it. There is another cloud of considerable richness which actually runs close up to the borders of the Milky Way. In the Southern Hemisphere the distribution is dominated by the great crowd of nebulæ in the larger cloud of Magellan. I take it, then, that the spiral nebulæ do not contradict the working hypothesis which we proposed for the stars. The nebulæ seem to be gathered into clouds also; but they are not in the plane of the star clouds—that is all. And note how simple the problem of the great Magellanic cloud has become. Upon our old theory we had to explain why the forces which everywhere else in the universe have driven the stars and nebulæ asunder have driven them together in profusion in the greater cloud. It was truly called a great riddle hard to solve. But so soon as we get rid of the idea of an organic whole, of separative forces, of one exceptional place which should provide the key to unlock the secret of the others, there seems to be no reason at all why things should not be just as they are. The stars are gathered in a series of clouds pretty much in one plane; we are in the middle of one that gives us stars all round us in the sky. Several others are comparatively near, and furnish the greater number of the fainter catalogue stars; the others that are further off draw apparently closer together by a perspective effect and make the Milky Way. Groups of stars that make the Pleiades and Hyades and Præsepe and Coma Berenices in the nearer clouds make the closer but still loose clusters of the further. There is one star cloud well out of the plane; that is the smaller Magellanic cloud. The spiral nebulæ, too, are in clouds that do not, as a rule, contain a great proportion of stars, though it may be remarked that the brighter nebulæ which alone we know may very well be in clouds comparatively near us, and the stars consequently as scattered as the nebulæ. Finally, there is one large and rich cloud, well out of the plane, which contains both stars and nebulæ of all sorts; that is the great cloud of Magellan. Is there any improbability that one cloud out of many should be a region specially favored whose riches are more varied than the average? I think not. There is coal in England and Belgium, China and the eastern United States; there is gold in California and Australia and the Rand. In Rhodesia the gold and the coal lie side by side. Let me repeat once more that I would not consider this cloud-view of the universe as anything more than an alternative working hypothesis which does seem to me to square with the facts in a very agreeable way. Its falsehood may not improbably be demonstrated on general grounds. Its truth can never be proved until we have a very great deal more knowledge of the sky than we have at present.

Aluminium foil is used largely as a substitute for tin foil. One kilogramme—2.2040 pounds—of the metal is spun into 32 square meters of thin sheet. Some of the sheets adhere together, and this is worked into powder.

THE CURIOUS FRUCTIFICATION OF THE FIG.

A GREAT many kinds of figs are found in commerce, because there are many cultivated varieties of the fig tree, each of which annually yields several crops of fruit, of different qualities. The complicated biological relations which connect these various figs, and the curious process by which the fruit is developed, are described in detail in a memoir recently published by M. Trabut. Some of the facts of greatest general interest are given in the following brief abstract which, for the sake of clearness, is confined chiefly to the wild fig (*Ficus Carica*), known in French as the *caprefiguier*, or goat fig.

It is well known that the fig is not a true fruit, in the sense in which the word fruit is employed by botanists. That is to say, it results from the transformation, not of a single flower, but of an inflorescence of peculiar form. The end of the floral axis is hollowed, or invaginated, and the numerous minute flowers are borne on the inside of the pocket-like receptacle thus formed, which communicates with the outer air only through a narrow orifice, covered with imbricated bracts, and which may become fleshy and form an edible fig.

The wild fig tree annually produces three crops of fruit, the development of each of which is intimately connected with that of the others. Late in autumn, after the leaves have fallen, the branches bear the small hard figs which the Kabyles call "ouaha" (Fig. 1, *A*). All the flowers in these figs are female, but they differ from the typical, or fertile, female flower (Fig. 2, *A*) by having very short styles and small stigmas (Fig. 2, *B C*). They are called "gall flowers," because their function is to receive the eggs of a small hymenopterous insect, *Blastophaga Psenes* (Fig. 3) and to harbor its larvæ, instead of seeds, in their ovaries during the winter. The adaptation of the flower to this function consists in the shortening of its style to the length of the ovipositor of the insect, which cannot reach the ovary of a normal female flower.

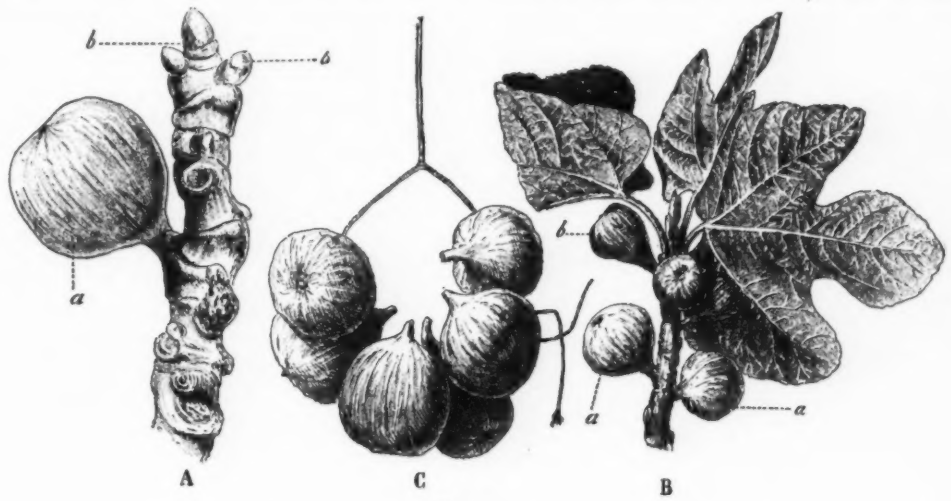


FIG. 1.

A, a branch of a wild fig tree at the beginning of winter; *a*, "ouaha," persisting through the winter; *b*, buds of "dokkar." B, branch in spring with "ouaha" (*a*) and "dokkar" (*b*). C, "dokkar" plucked and threaded for caprification.

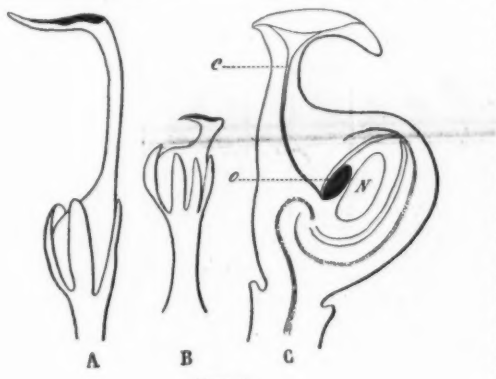


FIG. 2.

A, Diagram of perfect female flower of wild fig. B, Gall flower. C, Gall flower enlarged, showing stylar channel (*c*) through which the *Blastophaga* has introduced an egg (*o*) into the ovary and deposited it beside the ovule (*N*).

In the spring larger figs grow from the axillæ of the fallen leaves. These spring figs, or "dokkar," are also called male figs, because they contain male flowers in addition to gall flowers. The female *Blastophaga* flies that have been hatched and developed in the "ouaha," or autumn figs, now make their escape, enter the young spring figs and deposit eggs in the gall flowers of the latter. The insects which are hatched from these eggs reach maturity in June. The males, which are wingless, much larger than the females and furnished with powerful mandibles, cut their way out of the ovaries, or galls, in which they have been imprisoned and proceed to open the galls that contain females, and to fertilize the latter. The winged females then escape and, as they pass over the male flowers, which are situated near the orifice of the fig and are now in full bloom, the insects become covered with pollen, which they carry to a third crop of figs, the summer figs, or "djeha."

The "djeha," which make their appearance during the summer on shoots of the current year, contain flowers of three sorts: male flowers, modified female or gall flowers, and normal female flowers, capable of producing seeds on being fertilized. Their fertilization is effected by the female flies which have escaped from the "dokkar" or spring figs. These insects force their way through the narrow orifice of the young summer fig, often tearing off their wings in the operation, and deposit their eggs in its gall flowers, incidentally leaving on the stigmas of the perfect female flowers the pollen which they have brought from the spring figs. The pollen of the male flowers in the summer figs does not reach maturity until two months later, when the flies developed in the summer figs escape. The female insects then deposit their eggs in the autumn figs, as described at the outset, but the pollen which they bring with them from the summer figs is wasted, because the autumn figs contain no fertile female flowers.

We see, then, that of the three crops of figs borne by the wild fig tree, the "djeha," or summer figs, alone contain seeds, which owe their existence to the visits of insects laden with pollen from the "dokkar," or spring figs. Wild figs of all three sorts are, in general, dry and hard, though the "djeha" sometimes become slightly fleshy.

From these three sorts all the varieties of edible figs have been obtained by cultivation. Some have been developed from the "djeha" by the total suppression of both gall flowers and male flowers, some from the "dokkar" by suppression of the stamens and the complete sterilization of the gall flowers. These latter

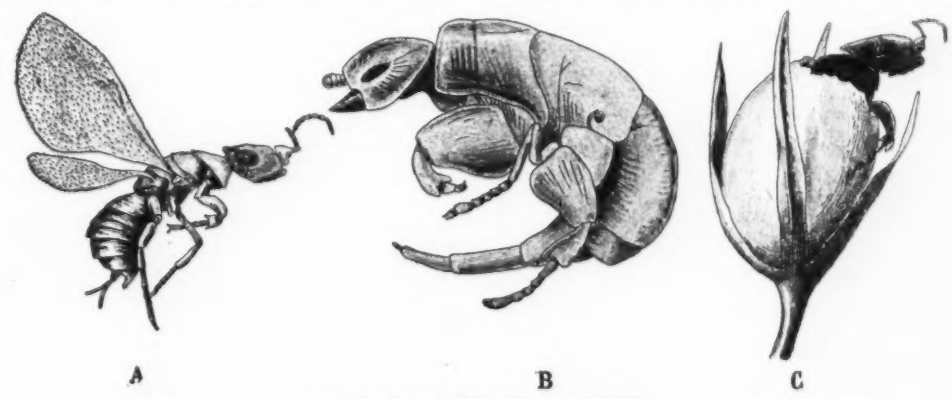


FIG. 3.—BLASTOPHAGA PSENES.

A, female; B, male; C, female escaping from gall, which a male has opened.

varieties are known as "bakor," or "figues fleurs." Finally, the "ouaha" are represented by edible figs in which all the flowers are sterile.

In this and analogous cases fertilization is useless, but when the figs contain perfect female flowers they do not develop and become fleshy unless they have been fertilized with wild fig pollen through the agency of *Blastophaga* flies. This necessity of insect intervention explains the common practice of "caprification," which consists in hanging on the cultivated fig trees wild "dokkar," or spring figs, containing ripe pollen and flies ready to make their escape (Fig. 1, *C*). In America and other lands in which the fig tree is not indigenous the successful cultivation of varieties in which fertilization of the flowers is essential to the development of the fruit becomes possible only after the introduction of the "dokkar."

The fruits of the cultivated varieties appear successively from June to August, during the whole of which period it is necessary to have ripe "dokkar" for fertilization. Though several early varieties of wild fig have been obtained by selection the earliest cultivated figs are ready for fertilization, in the mountains of Kabylia, before the "dokkar" of that region is in condition to furnish the pollenizing insects. Hence the fig growers are compelled to import "dokkar" from the plains and thus there has developed an extensive commerce in these wild spring figs, of which twenty dollars' worth is sometimes furnished by a single tree.

The following table gives the names applied, in various countries, to the three growths of figs:

	Autumn or winter.	Spring.	Summer.
Algeria.....		Bakor	Kermons
Algeria (wild)	Ouaha	Dokkar	Djeha
France.....		Figue-Fleur	Figue
Italy.....	Cimaruoli	Fiori	Pedagnuoli
Italy (wild)...	Mamme	Profichi	Mammoni
Portugal.....		Lampos	Vendimos

—From La Science au XXme Siècle.

ON THE PERCEPTION OF THE FORCE OF GRAVITY BY PLANTS.*

By FRANCIS DARWIN, F.R.S.

WHEN I had the honor of addressing this asscciation at Cardiff as president of the mother-section from which ours has sprung by fission, I spoke of the mechanism of the curvatures commonly known as tropisms. To-day I propose to summarize the evidence—still far from complete—which may help us to form a conception of the mechanism of the stimulus which calls forth one of these movements—namely, geotropism. I have said that the evidence is incomplete, and perhaps I owe you an apology for devoting the time of this section to an unsolved problem. But the making of theories is the romance of research; and I may say, in the words of Diana of the Crossways, who indeed spoke of romance, "The young who avoid that region escape the title of fool at the cost of a celestial crown." I am prepared for the risk in the hope that in not avoiding the region of hypothesis I shall at least be able to interest my hearers.

The modern idea of the behavior of plants to their environment has been the growth of the last twenty-five years, though, as Pfeffer has shown, it was clearly stated in 1824 by Dutrochet, who conceived the movements of plants to be "spontaneous"—i. e., to be executed at the suggestion of changes in the environment, not as the direct and necessary result of such changes. I have been in the habit of expressing the same thought in other words, using the idea of a guide or signal, by the interpretation of which plants are able to make their way successfully through the difficulties of their surroundings. In the existence of the force of gravity we have one of the most striking features of the environment, and in the sensitiveness to gravity which exists in plants we have one of the most widespread cases of a plant reading a signal and directing its growth in relation to its perception. I use the word perception not of course to imply consciousness, but as a convenient form of expression for a form of irritability. It is as though the plant discovered from its sensitiveness to gravity the line of the earth's radius, and then chose a line of growth bearing a certain relation to the vertical line so discovered, either parallel to it or across it at various angles. This, the reaction or reply to the stimulus is, in my judgment, an adaptive act forced on the species by the struggle for life. This point of view, which, as I regret to think, is not very fashionable, need not trouble us. We are not concerned with why the plant grows up into the air or down into the ground; we are only concerned with the question of how the plant perceives the existence of gravitation. Or, in other words, taking the reaction for granted, what is the nature of the stimulus? If a plant is beaten down by wind or by other causes into a horizontal position, what stimulative change is wrought in the body of the plant by this new posture?

It is conceivable in the case of a stem supported by one end and projecting freely in the air that the unaccustomed state of strain might act as a signal. The tissues on one side (the upper) are stretched, and they are compressed below: this might guide the plant; it might, in fact, have evolved the habit of rapid growth in the compressed side. This is only given as an illustration, for we know that the stimulus does not arise in this way, since such a plant, supported throughout its length, and, therefore, suffering no strain, is geotropically stimulated. The illustration is so far valuable, as it postulates a stimulus produced by weight, and we know from Knight's centrifugal experiment that weight is the governing factor in the conditions. Since we cannot believe that the stimulus arises from the strain as affecting the geotropic organ as a whole, we must seek for weight-effects in the individual cells of which the plant is built. We must, in fact, seek for weight-effects on the ectoplasm[1] of those cells which are sensitive to the stimulus of gravity.

If we imagine a plant consisting of a single apogeotropic cell we shall see that the hydrostatic pressure of the cell-contents might serve as a signal.

As long as the cell is vertical the hydrostatic pressure of the cell-sap upon the ectoplasm at *C* (Fig. 1) is equal to that at *D*. But the pressure on the basal wall, *B*, differs from that at *A* (the apical wall) by the weight of the column *A B*. If the plant be forced into the horizontal, the pressure at *A* and *B* becomes the same, while the pressure at *C* no longer equals that at *D*, but differs by the weight of the column *C D*. Here undoubtedly is a possible means by which the plant could perceive that it was no longer vertical, and would have the means of distinguishing up from down. So that if it were an apogeotropic plant it would need to develop the instinct of relatively accelerated growth on the side *D*, on which the pressure is greatest.

What is here roughly sketched is the groundwork of the theory of *graviperception*[2] suggested by Pfeffer[3] and supported by Czapek,[4] which I shall speak of as the radial pressure theory, and to which I shall return later.

It is obvious that there is another consideration to be taken into account, namely, that cells do not contain cell-sap only, but various bodies—nucleus, chloroplasts, crystals, etc.—and that these bodies, differing in specific gravity from the cell-sap, will exert pressure on the physically lower or physically higher cell-walls according as they are heavier or lighter than the cell-sap. Here we have the possibility of a sense-organ for verticality. As long as the stem is vertical and the apex upward the heavy bodies rest on the basal wall, and the plant is not stimulated to curvature; but if placed horizontally, so that the heavy bodies rest on the lateral cell-walls, which are now horizontal, the plant *is* stimulated to curve. This is known as the *statolith* theory.

It seems to me quite certain that the stimulus must originate either in the weight of solid particles or in the weight of the fluid in the cells, or by both these means together, and for this reason: Take the statolith theory first. There undoubtedly are heavy bodies

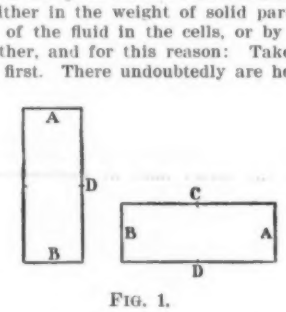


FIG. 1.

in cells; for instance, certain loose, movable starch-grains. Now, either these starch-grains are specialized to serve the purpose of graviperception or they are not. If they are so specialized, *cadit quaestio;* if they are not, there still remains this interesting point of view: the starch-grains fall to the lower end of the cells in which they occur; therefore, shortly before every geotropic curvature which has taken place since movable starch-grains came into existence, there has been a striking change in the position of these heavy cell-contents. Now, if we think of the evolution of geotropism as an adaptive manner of growth we must conceive plants growing vertically upward and succeeding in life, others not so behaving, and consequently failing. There will be a severe struggle tending to pick out those plants which associated certain curvatures with certain preceding changes, and therefore it seems to me that, if movable starch-grains were originally in no way specialized as part of the machinery of graviperception, they would necessarily become an integral part of that machinery, since the act of geotropism would become adherent to or associated with the falling of the starch-grains.

This argument must in fairness be applied to any other physical conditions which constantly precede geotropic curvature; it is therefore not an argument in favor of the statolith theory alone, but equally for the pressure theory, and cannot help us to decide between the two points of view.

Are there any general considerations which can help us to decide for or against the statolith theory? I think there are—namely, (1) analogy with the graviperceptive organs of animals; (2) the specialization and distribution of the falling bodies in plants.

(1) Berthold[5] (to whom the credit is due[6] of having first suggested that Dehnecke's falling starch-grains might function as originators of geotropic reaction) is perhaps somewhat bold in saying that "the primary effect of gravity" as regards stimulation must depend on the passive sinking of the heavier parts. Noll, too,[7] says that Knight's experiment depends on weight, and not the weight of complete parts of the plant-body, but of weight within the irritable structure. I cannot see that these downright statements are justified on direct evidence, and I accordingly lay some stress on the support of zoological evidence. It has been conclusively proved by Kreidl's[8] beautiful experiment that in the Crustacean Palæmon the sense of verticality depends on the pressure of heavy bodies on the inside of cavities now known as statocysts, and formerly believed to be organs of hearing. The point of the experiment is that when the normal particles are replaced by fragments of iron the Palæmon reacts toward the attraction of a magnet precisely as it formerly reacted toward gravity.

It is unfortunate that Noll's arguments in favor of the existence of a similar mechanism in plants were not at once followed by the demonstration of those easily visible falling bodies, which, in imitation more flattering than accurate, are called *statoliths*, after the bodies in the statocysts of animals. Personally I was convinced by Kreidl, as quoted by Noll, that here was the key to graviperception in plants. But it was not until the simultaneous appearance of Haberlandt's[9] and Nemec's[10] papers that my belief became active, and this, I think, was the case with others. The whole incident is an instance of what my father says somewhere about the difficulty of analyzing the act of belief. I find it impossible to help believing in the statolith theory, though I own to not being able to give a good account of the faith that is in me. It is a fair question whether the analogy drawn from animals gives any support to the theory for plants. The study of sense-organs in plants dates, I think, in its modern development, at least, from my father's work on root-tips, and on the light-perceiving apices of certain seedlings. And the work on this subject is all part of the wave of investigation into adaptations which followed the publication of the "Origin of Species." It is very appropriate that one of the two authors to whom we owe the practical working out of the statolith theory should also be one of the greatest living authorities on adaptation in plants. Haberlandt's work on sense-organs, especially on the apparatus for the reception of contact stimuli, is applicable to our present case, since he has shown that the organs for intensifying the effect of contact are similar in the two kingdoms. No one supposes that the whisker of a cat and the sensitive papilla of a plant are phylogenetically connected. It is a case of what Ray Lankester called homoplastic resemblance. Necessity is the mother of invention, but invention is not infinitely varied, and the same need has led to similar apparatus in beings which have little more in common than that both are living organisms.

But, whether we are or are not affected in our belief by the general argument from analogy, we cannot neglect the important fact that Kreidl proves the possibility of gravisensitiveness depending on the possession of statoliths. We must add to this a very important consideration—namely, that we know from Nemec's work[12] that an alteration in the position of the statoliths does stimulate the *statocyte*.[13] Such, at least, is, to my mind, the only conclusion to be drawn from the remarkable accumulation of protoplasm which occurs, for instance, on the basal wall of a normally vertical cell when that wall is cleared of statoliths by temporary horizontality. The fact that a visible disturbance in the plasmic contents of the statocyte follows the disturbance of the starch-grains seems to me a valuable contribution to the evidence.

There is one other set of facts of sufficiently general interest to find a place in this section. I mean Haberlandt's result,[14] also independently arrived at by myself, that when a plant is placed horizontally and rapidly shaken up and down in a vertical plane the gravistimulus is increased. This is readily comprehensible on the statolith theory, since we can imagine the starch-grains would give a greater stimulus if made to vibrate on one of the lateral walls, or if forced into the protoplasm, as Haberlandt supposes. I do not see that the difference in the pressure of the cell-sap on the upper and lower walls (i. e., the lateral walls morphologically considered) would be increased. It would, I imagine, be rendered uneven; but the average difference would remain the same. But in the case of the starch-grains an obvious new feature is introduced by exchanging a stationary condition for one of movement. And though I speak with hesitation on such a point, I am inclined to see in Haberlandt's and my own experiments a means of distinguishing between the pressure and statolith theories. Noll,[15] however, considers that the shaking method is not essentially different from that of Knight's experiment, and adds that the result might have been foreseen.

DISTRIBUTION.

As far as I know, the development of *statoplasts*[16] has not been made out. Are they at first like ordinary immovable amyloplasts; and, if so, by what precise process do they become movable? Where the two forms of starch are seen in close juxtaposition the difference between them is striking, and it is hardly possible to doubt that these differently situated bodies have dif-

* Read before the British Association for the Advancement of Science.

[1] See Noll's ingenious reasoning by which he makes it clear that the stationary ectoplasm, not the flowing endoplasm, is the seat of stimulation. Noll (88).

[2] I propose this term in place of *geoaesthesia*, which does not lend itself to the formation of adjectives, or the hybrid word *geoperception*. By not using the form "geo" we avoid any necessary connection with geotropism, and may thus use terms compounded of *gravi* for phenomena other than those of curvature.

[3] Pfeffer (81).

[4] Czapek (98), (01).

[5] "Protoplasmamechanik," 1886, p. 73. I was directed to this passage by Pfeffer's discussion ("Pflanzenphysiologie," ed. 2, II., p. 641).

[6] Berthold's remarks seem not to have received much notice, and it was not till the publication of Noll's "Heterogene Induction," 1892, that a form of the statolith theory was at all widely recognized as a possible explanation.

[7] "Heterogene Induction," p. 41.

[8] Kreidl (93).

[9] Haberlandt (00).

[10] Nemec (00).

[11] Haberlandt (01).

[12] Nemec (01, p. 153).

[13] *Id est*, the cells containing statoliths.

[14] Haberlandt (03) and F. Darwin (03).

[15] Noll (03, p. 131).

[16] I would suggest the word *statoplast* in place of the cumbersome expression *movable starch-grains*.

ferent functions. In a seedling *Phalaris canariensis* the apical part has only falling starch-grains, while lower down both forms occur. It suggests a corresponding distribution of graviperception; and, as a fact, the seedling is gravisensitive throughout, but is especially so at the apex. If this is not the meaning of the statoplasts we must find some other. For instance, are the loose starch-grains connected in an unknown way with heliotropic sensitiveness, which often has the same distribution as that of graviperception? Or is the looseness of starch connected in some way with food storage? Is it to allow of starch being closely packed in part of the cell, leaving the rest of the space free?

Again, the most striking general fact about the distribution of falling starch is its presence in the endodermis.[17] If we believe that the endodermis is essentially a tissue of gravisensitive cells we can understand the striking fact that it contains loose starch only as long as the stem is capable of growth curvature.[18] Otherwise the theories of the function of the endoderm, which have never been very satisfactory, have the additional burthen of explaining this last-named fact.

According to Haberlandt (09), some monocotyledons the leaves of which contain no starch have falling grains in the endodermis. Nemec (01, p. 24) quotes from Sachs the case of *Allium cepa*, where statoplasts occur in the root-cap, the endoderm, and punctum of the seedling, and not elsewhere. Then we have occurrence of starch in the pulvinus of grasses and not in the rest of the haulm. Viscum is not geotropic, and has no statoplasts. In the holdfast roots of Hedera and Marcgravia there is no starch, and in Hoya, Pothos, and Ficus the starch is not movable, and these roots are not geotropic.[19]

Jost (02) brought forward, as a serious objection to the statolith theory, the fact that tertiary roots possess statoliths, but are not sensitive to gravitation. This objection has been overcome by the discovery[20] that when the primary root is cut off and a secondary assumes its place and manner of growth, the tertiaries springing from it are diageotropic, and thus have at least an occasional use for their statoplasts.

I have shown[21] that the cotyledon of Setaria and Sorghum is the seat of graviperception, and it is there that the statoplasts are found.[22] Wiesner (02) was unable to find statoliths in the perianth-segments of *Oxalis nobilis*, which are geotropic, nor in those of *Oxalis miniata*, which are not geotropic. Here would seem to be a serious objection to the statolith theory, but Nemec (04, p. 58), on repeating Wiesner's observations, finds, on the contrary, a confirmation of his own views. For movable starch-grains occur in the perianth of *O. nobilis*, but not in those of *O. miniata*. In the case of roots the distribution of the statoplasts is especially worthy of note. Physiologists have gradually come to believe that my father[23] was right in his view that the organ of graviperception is in the tip of the root; and it is there—generally in the root-cap—and there only, that statoplasts are found. But these facts do not entirely harmonize with the statolith theory, as I shall show later on in the section devoted to experimental evidence. Here I will only add that the group of statocytes in the root are strongly suggestive of some special function, and those who deny that they form an organ of graviperception must find some other use for them; and this will be no easy task. I must not omit to mention the ingenious experiments of Piccard (04), which prove (if they prove anything) that the root-tip is not the seat of the graviperception, but that this quality is found in even greater perfection in the growing region of the root. But until the whole of the other experimental evidence is proved to be illusory, I must suspend judgment on Piccard's results and treat the question provisionally from our previous standpoint.

The existence of statoliths in regions which have ceased to be capable of ordinary geotropic curvature is at first sight a difficulty. Thus Miss Pertz has found in the pith of the watercress (*Nasturtium officinale*) the most perfect statoplasts, and this in winter, when the capacity for geotropic curvature was probably absent. Again, she has found movable starch in the xylem elements and in the cortex of a number of trees. In this case we must remember that, according to Meischke (99), Jost (01), and Baranetzky (01), woody branches of several years' growth are capable of geotropic curvature. If so, graviperceptive organs must exist. We must remember, too, that in the regeneration of cuttings, Vöchting (78) has shown that gravitation has an influence in certain cases; such cuttings must therefore have organs of graviperception. Or, if this is not granted as necessary, it seems to me conceivable that falling starch-grains, though made use of, and in a certain sense specialized, for graviperception, should nevertheless exist and serve other purposes in the economy of the plant. But this question needs further detailed work.

Lastly, as part of the general question of distribution, it must be clearly pointed out that in a large number of plants, such as Algæ and Fungi, no statoliths are known to exist, though their complete absence has not been proved.[24] Here we must either believe in Noll's minute and hitherto unseen statoliths or in a different mechanism, such as hydrostatic pressure. There is no more impossibility in this state of things than in the presence of statoliths in Palæmon and their absence in higher animals. And I am glad to note that both Pfeffer and Czapek are not disinclined to believe in the possibility of various forms of graviperception.

(To be continued.)

[17] See Haberlandt (03) for a description of certain special cases of statocyte-tissue, apparently replacing the endodermis.

[18] According to Haberlandt (03, p. 451), it is easy to be deceived in asserting that the endoderm contains no starch. Thus Fischer failed to find it in outgrown stems of some plants which possess it when young. Tondera (03) asserts that in certain Cucurbits the falling starch is only present in the older parts no longer capable of geotropism. But Miss Pertz, who has examined most of the species investigated by Tondera, finds statoplasts in the young parts where he failed to find these. Tondera makes some interesting remarks on the distribution of starch in the Cucurbits harmonizing with Heine's storehouse theory. It is obviously difficult in the case of the endoderm to distinguish between starch serving as a reserve and starch serving as part of the mechanism of perception. I see no reason why the second function should not be evolved from the first.

[19] Haberlandt (03, p. 461).

[20] Darwin and Pertz (04).

[21] F. Darwin (99).

[22] According to Nemec they occur to some extent in the hypocotyl of Panicum.

[23] C. Darwin ("Power of Movement").

[24] See Nemec (*Beihefte Bot. Central.*, B. xvii. 1904, p. 59), where he describes the cases and the occurrence of statoliths in the mosses and liverworts. Giesenhagen (01) has described heavy bodies at the tips of the rhizoids of *Chara* which fall to the physically lower side.

PLANT NUTRITION.

THE main facts of the nutrition of the plant have been so long established that it is not always realized how much still remains unknown. It has become a commonplace of the text-books that the plant needs nitrogen, phosphoric acid, potash, often in excess of the quantities present in a normal soil; so that these substances alone are considered of manurial value, other necessary materials like lime, magnesia, iron, sulphuric acid and chlorine being practically never lacking under natural conditions. But the function of these substances in the development of particular plants, the manner in which the character of the crop is affected by an excess or a deficit, is still imperfectly apprehended. We realize the dependence of vegetative development upon the supply of nitrogen, and how an excess defers maturity; we are also beginning to gather facts as to the manner in which an overplus of nitrogen causes alterations in the structure of the tissues and variations in composition of the cell contents that result in increased susceptibility to fungoid attack. Again, it is clear that potash takes a fundamental part in the process of assimilation, the production of carbohydrate in all forms being dependent on the supply of potash; but of the manner or the location of the action we have no knowledge. Our ignorance of the function of phosphoric acid is even greater; broadly speaking, it hastens maturity, and is bound up with such final processes in the plant's development as the elaboration of seed. With this we naturally correlate on *à priori* grounds the presence of phosphorus in the nucleo-proteids; but there is no particular evidence that excess of phosphoric acid leads to increased assimilation of nitrogen.

Some of the barley plots at Rothamsted show this very clearly; where there has been no phosphatic, but a nitrogenous, manuring for the last fifty years, the amount of nitrogen assimilated by the crop is diminished, but the gross production of dry matter is still further diminished. By the addition of phosphoric acid the gross production is increased to a greater degree than the amount of proteid formed is increased, so that the crop shows now a smaller percentage of nitrogen and a lower ratio of nitrogen to phosphoric acid than on the plots which are experiencing phosphoric-acid starvation. In other words, where an excess of nitrogen is available the amount assimilated does not increase *pari passu* with the amount of phosphoric acid which the plant can obtain.

But with these three substances all exact knowledge ceases; magnesia, sulphuric acid, and chlorine are invariable and necessary constituents of all plants, yet their function and their practical effects are still unknown. To take a further example, it was early in the history of agricultural science that silica was discovered to be the chief constituent of the ash of cereals and of a few other plants. Liebig's term of "silica plants" still survives to show the importance once attached to this body, and the earlier experimenters with manures used soluble silicates with the idea of thereby increasing the stiffness of straw. But further investigations showed that cereals could be brought to maturity without any supply of silica, and that the stiffness of the straw was a physiological matter in no way conditioned by silica. As a consequence this plant constituent has now been disregarded for a long time. But it is idle to suppose that a substance present, for example, to the extent of 60 per cent or so in the ash of the straw of wheat, has no part to play in the nutrition of the plant. Among the Rothamsted experiments there are fortunately some barley plots which have received soluble silica for many years, and a recent examination of the material grown on these plots begins to cast some light on the function of silica. Its effect upon the plant is in some way parallel to that of phosphoric acid; on the plots which have had no phosphatic manure for more than fifty years an addition of soluble silica increases the crop, increases the proportion of grain and hastens the maturity in exactly the same fashion, though to a less degree, than an addition of phosphoric acid. The results point to the plant rather than the soil as being the seat of the action; a plant that is being starved of phosphoric acid can economize and make more use of its restricted portion if a quantity of soluble silica be available. There is no possibility of replacing phosphoric acid by silica in the general nutrition of the plant, but the abundance of silica at the disposal of the cereals certainly enables them to diminish their call for phosphoric acid from the soil.—Science.

SCIENCE NOTES.

Before the awakening to the needs and possibilities of forestry and when the forests were considered inexhaustible, indifference and inaction when forest fires occurred was not unnatural. These conditions, however, are now of the past. The end of the virgin timber supply is in sight, and the improved tone of the lumber market is enabling lumbermen to dispose of inferior material and to realize better prices for all grades. These changes are making it profitable for timber owners to cut more conservatively, and to hold their land for future timber production.

Some careful studies have been made dealing with the sources of organic nitrogen in certain of the molds, but owing to the very great variety of fungous habitats, further studies may indicate unusual specialization—perhaps even to such extent as is now known to be true with the bacteria. Saida has confirmed and extended the early work of Puriewitsch and others, clearly demonstrating that under certain conditions some of the fungi are able to utilize to a variable degree the atmospheric nitrogen. It would be interesting in this connection to give further attention to various groups of saprophytic fungi. In a public lecture Moore has recently made known the results of remarkably definite experiments showing that the organism (or organisms) of leguminous tubercles assimilates free nitrogen apart from its hosts, and that, therefore, the symbiotic association gives the parasite no nitrogen-assimilating advantages. Moreover, this nitrogen assimilating capacity increases under conditions of artificial culture, and this increased power is heritable to a considerable extent at least. This is an important fact and deserves further attention.

A piece of work, bringing great surprise among biologists as well as the rest of the thinking world, has been given to us within a year or two, namely, that unfertilized eggs have been made to develop in a normal way by subjecting them to certain inorganic chemical substances, such as magnesium chloride. It has been repeated by so many there is no doubt about it now, but its significance is that life itself is a chemical process and does not necessarily depend upon antecedent life any further than such structure contains chemical combinations of proper sort, and that if these be provided in other ways life and growth will result. This research has no more than begun and we may be on the lookout for surprises. A French biologist reports that if an egg be properly cut into as many as sixteen pieces it will develop into sixteen individuals, differing only in size from the normal individual. This opens out a new field, the philosophical importance of which exceeds its biological importance, as can be seen in a minute's thinking. What the outcome will be no one can tell now, but we may envy the biologists who devote their time to such investigations.

Chemistry has a wonderful field where one may work intelligently in a constructive way. Compounds both inorganic and organic have been produced in great variety, and some chemists are at work trying to make artificially many things which one has to depend upon nature for now—thus quinine, now used in such great quantity; others are sugar or albumen for food, or nitrates for fertilizers, and so on. All these, if produced on a commercial scale, would be of enormous worth to the world. Aside from these the chemical preparation of antitoxins for the relief and cure of many diseases, cholera, plague, yellow fever, typhoid fever, are all being sought for with a great probability that they will be discovered and the life of men be saved for many years. I wish I could say that, if life be saved and kept by such artificial means, mankind would not seek other ways of decimating its ranks. The average life of the Jews is upward of seventy years. If all men had the same degree of vitality the world would be so crowded in a hundred or two hundred years that only the loss of fertility would save the necessity for famine, war, and pestilence. Chemistry may give us a boon and leave nature to find some other resource for reducing numbers. That such resource would be radically different from her past methods is not very probable.

If we look at the physicians of the present we find three classes have been founded as a result of rationalism in medicine: First, the general practitioner who of necessity must be brought in contact with all forms of human ills; second, the specialist who happily lives in a community where the physician who devotes his whole time to one particular study can be supported; third, the health officer who is the forerunner of the physician of the future. The foes of rational medicine at the present time are, first, the quack, a man possessing, possibly, high medical training and skill, but unfortunately devoid of those principles of ethics without which the honorable practice of a profession is impossible; second, the charlatan, a man necessarily devoid of any medical training or ability, who plays upon the feelings of his patients and administers nostrums of no value and applied with no science. The third foe of rational medicine is the impersonal physician, namely, the nostrum, the patent medicine and the proprietary remedy. It is appalling to think of the thousands and thousands of our fellow citizens who pin their faith to these alleged remedies. Some of them have value; they are in fact often the very remedies which are described in the materia medica and the pharmacopœia and administered by physicians, but distributed as they are, with absurd claims of efficiency, taken as they are, without the advice or consent of a physician, they become not only one of the greatest foes of rational medicine, but one of the greatest dangers to the public at large.

ENGINEERING NOTES.

Cast iron has ordinarily—unlike wrought iron or steel—great capacity for resisting rust, and will, after many years of absolute neglect, appear but little the worse; an advantage which is the more pronounced when considered relatively to the greater thickness of the thinnest parts in cast-iron girders, the percentage of waste being proportionately lessened. Cast iron does, however, behave somewhat badly in sea-water, the metal sometimes losing its original character, and becoming in time quite soft; though, if not worn away, as by the attrition of shingle, maintaining its original bulk.

Most modern locomotive piston-valve engines are of the heavy type, with cylinders much larger than were formerly used, and in a great many cases the enginemen have not taken the care of them that they did of the smaller engines; but after the engines have been in service for a while the men become accustomed to them, and all trouble generally disappears. There is no reason why the frames and cylinders on piston valve engines, if properly designed, are subject to breakage any more than the slide-valve engines, if proper provision is made against careless handling. There are four essential points to be considered—cost, maintenance, steam distribution, and fuel economy. There seems to be no question that the first cost of the piston valve is less than the slide valve on simple engines, and where four-cylinder compound types of engines are used, it takes the place of two valves and reduces the motion to that of a simple engine.

It is well known that a high boiler pressure gives a greater amount of expansion and better economy in proportion to the fuel burned. Even with simple engines in which it is not possible to obtain the full advantage of expansion, the high pressure of steam, which is drier and contains a larger number of heat units in proportion to the volume, gives the best results. Every boiler should be designed for not less than 150 pounds pressure per square inch. Even if it is not possible to utilize the full pressure, the boiler will be stronger, will last longer and will be a better investment in the long run. In this respect, the water-tube or some form of internally fired boiler in which the shell plates are not exposed to the high temperature of the furnace is certainly safer than the horizontal return tubular boiler, because for large units intended to carry high pressure, the shell plates and seams must be of considerable thickness, and being directly exposed to the hottest part of the fire, are almost sure to give trouble, especially if there be any scale or sediment in the water which is liable to settle on the bottom directly over the fire.

The testing engineer acts in a three-fold capacity. He is either an investigator or a counselor or a judge. He is finding out new truths, he is protecting the interests of his client, the producer, or he is determining by his tests that contracts are being fulfilled, or specifications lived up to, in the interests of his client, the consumer. While all three forms of the testing engineer may be and often are engaged in research, in investigating a knotty problem, or devising means of demonstrating a point, it is perhaps more commonly the work of what may be called the unattached testing engineer to make investigations. The professors in colleges, especially those having a genius for experiment, and indeed independent investigators, who as the result of business shrewdness or by good fortune are so situated that they are not compelled to struggle for an existence, are continually adding to the sum of human knowledge by their tests and experiments while laboring in this field. They have no clients to satisfy, no employer's interests to defend and no antagonisms to overcome, except perchance the unwillingness of nature to yield up her secrets. Their loyalty is to the truth alone, their stimulus their zeal for knowledge, and their reward the approbation of their fellows. These seem to be almost ideal conditions for securing the truth, and it would seem as though results obtained by such experimenters, or testing engineers, and under such conditions, ought to be accepted and acted on without question.

Superheated steam is supposed to have been first applied to locomotives on the Chicago, Burlington & Quincy Railway in 1870, the front tube sheet being set back some distance into the boiler, and the superheater consisting of a separate cylinder in which the tubes formed practically a continuation of the boiler tubes and into which the steam entered by the dry pipe, and from it passed to the cylinders by pipes connected to the bottom. Such an apparatus could not have actually superheated the steam to any great extent, but it showed some economy which was not, however, considered sufficient to pay for its increase in cost and the trouble of maintaining it, and it was subsequently abandoned. The present development in the application of superheated steam to locomotives is due to Messrs. Garbe and Muller, of the Prussian State Railways, who in 1898 arranged to equip two engines, Hanover No. 74, built by the Vulcan Company, of Stettin, and Cassel No. 131, built by Henshel & Co., the design being prepared by Mr. Schmidt. In a paper read by Mr. Garbe in 1902, before the Berlin branch of the Institution of German Engineers, he related the various reasons that led him to a consideration of the advantages of superheated steam, and discussed in a comprehensive way the benefits derived from its use and the results at that time obtained. This paper is of special interest, as it describes the first modern application of superheated steam to a locomotive, and shows it to have been a decided success.

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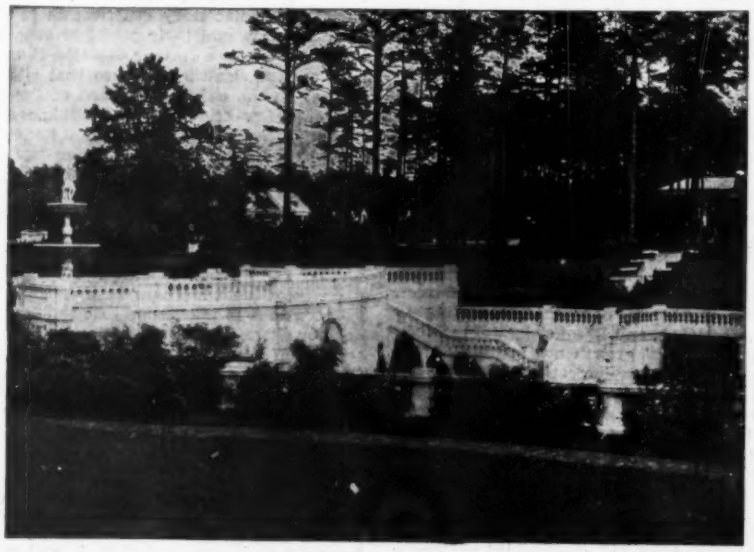

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